Snohomish County Drainage Manual

Volume V Runoff Treatment BMPs

Test 3

January July 20210 Ecology Review DRAFT

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Chapter 1 Introduction

1.1 Purpose of this Volume

Best Management Practices (BMPs) are schedules of activities, prohibitions of practices, maintenance procedures, managerial practices, or structural features that prevent or reduce adverse impacts to waters of Washington State. As described in Volume I of this stormwater manual, BMPs for long-term management of stormwater at developed sites can be divided into three main categories:

- BMPs addressing the amount and timing of stormwater flows;
- BMPs addressing prevention of pollution from potential sources; and
- BMPs addressing treatment of runoff to remove sediment and other pollutants.

This volume of the stormwater manual focuses on the third category, treatment of runoff to remove sediment and other pollutants at developed sites. The purpose of this volume is to provide guidance for selection, design and maintenance of permanent runoff treatment facilities.

BMPs for controlling stormwater flows and pollutant sources are presented in Volumes III and IV, respectively.

1.2 Content and Organization of this Volume

Volume V of the stormwater manual contains 12 chapters. Chapter 1 serves as an introduction and summarizes available options for treatment of stormwater. Chapter 2 outlines a step-by-step process for selecting treatment facilities for new development and redevelopment projects. Chapter 3 presents treatment facility "menus" that are used in applying the step-by-step process presented in Chapter 2. These menus cover different treatment needs that are associated with different sites. Chapter 4 discusses general requirements for treatment facilities. Chapter 5 presents information regarding on-site stormwater management BMPs. Chapters 6 through 11 provide detailed information regarding specific types of treatment identified in the menus. Chapter 12 discusses other BMPs for which the Washington State Department of Ecology has approved specific uses.

The appendices to this volume contain more detailed information on selected topics described in the various chapters.

1.3 How to Use this Volume

This volume contains information necessary to design, construct, and maintain BMPs for stormwater treatment. This information shall be used in conjunction with engineering standards and specifications set forth in Snohomish County Engineering Design and Development Standards.

1.4 Runoff Treatment Facilities

1.4.1 General Considerations

Runoff treatment facilities are designed to remove pollutants contained in stormwater runoff. The pollutants of concern include sand, silt, and other suspended solids; metals such as copper, lead, and zinc; nutrients (e.g., nitrogen and phosphorus); certain bacteria and viruses; and organics such as petroleum hydrocarbons and pesticides. Methods of pollutant removal include sedimentation/settling, filtration, plant uptake, ion exchange, adsorption, and bacterial decomposition. Floatable pollutants such as oil, debris, and scum can be removed with separator structures.

1.4.2 Maintenance

Maintenance requirements and standards for drainage facilities are set forth in Chapter 7.54 SCC, and Chapter 4.6 of this vVvolume V, and in Volume VI of theis Drainage Mmanual.

1.4.3 Treatment Methods

Methods used for runoff treatment facilities and common terms used in runoff treatment are discussed below:

- Wetpools. Wetpools provide runoff treatment by allowing settling of particulates during
 quiescent conditions (sedimentation), by biological uptake, and by vegetative filtration.
 Wetpools may be single-purpose facilities, providing only runoff treatment, or they may be
 combined with a detention pond or vault to also provide flow control. If combined, the
 wetpool facility can often be stacked under the detention facility with little further loss of
 development area.
- Biofiltration. Biofiltration uses vegetation in conjunction with slow and shallow-depth flow for runoff treatment. As runoff passes through the vegetation, pollutants are removed through the combined effects of filtration, infiltration, and settling. These effects are aided by the reduction of the velocity of stormwater as it passes through the biofilter. Biofiltration facilities include swales that are designed to convey and treat concentrated runoff at shallow depths and slow velocities, and filter strips that are broad areas of vegetation for treating sheet flow runoff.
- Oil/Water Separation. Oil/water separators remove oil floating on the top of the water. There are two general types of separators the American Petroleum Institute (API) separators and coalescing plate (CP) separators. Both use gravity to remove floating and dispersed oil. API separators, or baffle separators, are generally composed of three chambers separated by baffles. The efficiency of these separators is dependent on detention time in the center, or detention chamber, and on droplet size. CP separators use a series of parallel plates, which improve separation efficiency by providing more surface area, thus reducing the space needed for the separator. Oil/water separators must be located off-line from the primary conveyance/detention system, bypassing flows greater than the water quality design flow. Other devices/facilities that may be used for removal of oil include linear sand filters and proprietary devices that have received a use designation for oil removal from Ecology. Oil

- control devices/facilities should always be placed upstream of other treatment facilities and as close to the source of oil generation as possible.
- **Pretreatment.** Presettling basins are often used to remove sediment from runoff prior to discharge into other treatment facilities. Basic treatment facilities can also be used to provide pretreatment. Pretreatment often must be provided for filtration and infiltration facilities to protect them from clogging or to protect ground water. Appropriate pretreatment devices include a presettling basin, wet pond/vault, biofilter, constructed wetland, or oil/water separator. In addition, the Washington State Department of Ecology has given General Use Level and Conditional Use Level designations for pretreatment to a number of patented devices. More information can be found in Chapter 12 of this volume.
- Infiltration. Treatment with infiltration refers to the use of the filtration, adsorption, and biological decomposition properties of naturally-occurring soils to remove pollutants as stormwater infiltrates into the ground. Infiltration can provide multiple benefits including pollutant removal, peak flow control, ground water recharge, and flood control. However, one condition that can limit the use of infiltration is the potential adverse impact on ground water quality. To adequately address the protection of ground water when evaluating infiltration it is important to understand the difference between soils that are suitable for runoff treatment and soils only suitable for flow control. Sufficient organic content and sorption capacity to remove pollutants must be present for soils to provide runoff treatment. Examples are silty and sandy loams. Coarser soils, such as gravelly sands, can provide flow control but are not suitable for providing runoff treatment. The use of coarser soils to provide flow control for runoff from pollutant generating surfaces must always be preceded by treatment to protect ground water quality. Thus, there will be instances when soils are suitable for treatment but not flow control, and vice versa.
- **Filtration.** Filtration refers to the use of various media such as sand, perlite, zeolite, and carbon, to remove low levels of total suspended solids (TSS). Specific media such as activated carbon or zeolite can remove hydrocarbons and soluble metals. The Washington State Department of Ecology has given General Use Level and Conditional Use Level designations for treatment to a number of patented filter devices. More information can be found on the Ecology web site.
- **Bioretention.** Bioretention facilities use a special imported soil mix that functions as a granular filtration medium to provide stormwater treatment. In addition, specific vegetation is planted to maintain the soil's ability to adsorb pollutants, and to absorb and degrade pollutants captured by the soil. Bioretention facilities can be constructed as a special kind of infiltration basin that is overexcavated and partially refilled with the bioretention soil mix, in which case the facility is a combination flow control / treatment system. Alternatively, a bioretention system can be designed with an underdrain, which reduces or eliminates the flow control function, or the bioretention soil mix can be housed in a vault. Bioretention facilities constructed according to the requirements of this manual provide enhanced treatment.

Chapter 2 Treatment Facility Selection Process

See Volume I, Chapters 2 and 4 for the treatment facility selection process.

Chapter 3 Treatment Facility Menus

See Volume I, Chapter 4 for the treatment facility selection menus.

5

Chapter 4 General Requirements for Stormwater Facilities

4.1 Design Volume and Flow

4.1.1 Water Quality Design Storm Volume

See Volume III, Chapter 2 for water quality design volume determination.

The water quality design storm volume is the volume of runoff predicted from a 24 hour storm with a 6 month return frequency, or, alternatively, the 91st percentile, 24 hour runoff volume indicated by an approved continuous runoff model.

Wetpool facilities are sized based upon use of the NRCS (formerly known as SCS) curve number equations in Volume III, Chapter 2 for the 6-month, 24-hour storm. Treatment facilities sized by this simple runoff volume-based approach are the same size whether they precede detention, follow detention, or are integral with the detention facility (i.e., a combined detention and wetpool facility).

Unless amended to reflect local precipitation statistics, the 6-month, 24-hour precipitation amount may be assumed to be 72 percent of the 2-year, 24-hour amount. Precipitation estimates of the 6-month and 2-year, 24-hour storms for certain towns and cities are listed in Volume I, Appendix I B. For other areas, interpolating between isopluvials for the 2-year, 24-hour precipitation and multiplying by 72% yields the appropriate storm size. Isopluvials for 2-year, 24-hour amounts for Western Washington are reprinted in Volume III.

4.1.2 Water Quality Design Flow Rate

See Volume III, Chapter 2 for information on approved continuous runoff hydrologic models for determining the water quality design flow rate.

The water quality design flow rate for treatment systems downstream of detention facilities is the full 2-year release rate from the detention facility.

The water quality design flow rate for treatment systems upstream of detention facilities, or for projects in which detention is not required, is the flow rate at or below which 91% of the runoff volume, as estimated by an approved continuous runoff model, will be treated. All BMPs except wetpool types shall use the 15 minute time series from an approved continuous runoff model.

Design criteria for treatment facilities are assigned to achieve the applicable performance goal at the water quality design flow rate (e.g., 80 percent TSS removal).

For treatment facilities not preceded by an equalization or storage basin, and when runoff flow rates exceed the water quality design flow rate, the treatment facility should continue to receive and treat the water quality design flow rate to the applicable treatment performance goal. Only the higher incremental portions of flow rates are bypassed around a treatment facility. Snohomish County encourages design of systems that engage a bypass at higher flow rates provided the reduction in pollutant loading exceeds that achieved with bypass at the water quality design flow rate.

Treatment facilities preceded by an equalization or storage basin may identify a lower water quality design flow rate provided that at least 91 percent of the estimated runoff volume in the time series of an approved continuous runoff model is treated to the applicable performance goals (e.g., 80 percent TSS removal at the water quality design flow rate and 80 percent TSS removal on an annual average basis).

Runoff flow rates in excess of the water quality design flow rate can be routed through the facility provided a net pollutant reduction is maintained.

4.1.3 Flows Requiring Treatment

Runoff from pollution-generating hard surfaces and pollution-generating pervious surfaces must be treated according to the requirements set forth in Chapters 2 and 4 of Volume I of this manual.

Drainage from hard surfaces that are not pollution-generating need not be treated and may bypass runoff treatment, if the drainage is not mingled with runoff from pollution-generating surfaces. If runoff from non-pollution generating surfaces reaches a runoff treatment BMP, flows from those areas must be included in the sizing calculations for the BMP. Once runoff from non-pollution generating areas is mixed with runoff from pollution-generating areas, it cannot be separated before treatment.

4.1.4 Minimum Treatment Facility Size

The minimum design flow rate for treatment facilities based on this criterion is 0.0081 cfs. The minimum design volume for treatment facilities based on this criterion is 405 cf. No BMP shall be designed smaller than that required to accommodate the minimum flow rate or volume.

The treatment requirement is to treat at least 91% of the post-development runoff file as predicted by the WWHM or another an approved continuous runoff hydrologic model. The WWHM-2012 has a feature which allows the user to track the amount of stormwater that has passed through LID BMPs. If the LID BMP qualifies as a treatment facility (i.e., bioretention, permeable pavement with a sand sublayer or native soils that meet the soil suitability requirement), the total amount of runoff that passes through the BMP counts towards meeting the 91% requirement.

4.2 Sequence of Facilities

The Enhanced Treatment and Phosphorus Removal Menus described in Volume I, Chapter 4, include treatment options in which more than one type of treatment facility is used. In those options, the sequence of facilities is prescribed. This is because the specific pollutant removal role of the second or third facility in a treatment often assumes that significant solids settling has already occurred. For example, phosphorus removal using a two-facility treatment relies on the second facility (sand filter) to remove a finer fraction of solids than those removed by the first facility.

In general, all treatment facilities may be installed upstream of detention facilities, although presettling basins are needed for sand filters and infiltration basins. However, not all treatment facilities can function effectively if located downstream of detention facilities. Those facilities that treat unconcentrated flows, such as filter strips, are usually not practical downstream of

detention facilities. Other types of treatment facilities present special problems that must be considered before placement downstream is advisable.

For instance, prolonged flows discharged by a detention facility that is designed to meet the flow duration standard may interfere with proper functioning of basic biofiltration swales and sand filters. Grasses typically specified in the basic biofiltration swale design will not survive. A wet biofilter design would be a better choice.

Prolonged flows in sand filters may cause the sand to become anoxic and release phosphorus previously captured within the filter. To prevent long periods of sand saturation, adjustments may be necessary after the sand filter is in operation to bypass some areas of the filter. This bypassing will allow them to drain completely. It may also be possible to employ a different type of facility that is less sensitive to prolonged flows.

Oil control facilities must be located upstream of treatment facilities and as close to the source of oil-generating activity as possible. They should also be located upstream of detention facilities, if possible.

Table 5.1 summarizes placement considerations of treatment facilities in relation to detention.

Table 5.1 – Treatment Facility Placement in Relation to Detention			
Water Quality Facility	Preceding Detention	Following Detention	
Basic biofiltration swale	OK	OK. Prolonged flows may reduce grass survival. Consider wet biofiltration swale	
Wet biofiltration swale	OK	OK	
Filter strip	OK	No—must be installed before flows concentrate.	
Basic or large wetpond	OK	OK—less water level fluctuation in ponds downstream of detention may improve aesthetic qualities and performance.	
Basic or large combined detention and wetpond	Not applicable	Not applicable	
Wetvault	OK	OK	
Basic or large sand filter or sand filter vault	OK, but presettling and control of floatables needed	OK—sand filters downstream of detention facilities may require field adjustments if prolonged flows cause sand saturation and interfere with phosphorus removal.	
Stormwater treatment wetland/pond	OK	OK—less water level fluctuation and better plant diversity are possible if the stormwater wetland is located downstream of the detention facility.	

4.3 Setback and Separation Distances, Slopes, and Embankments

4.3.1 Separation Distances

Setback and separation distances for drainage facilities shall be provided in accordance with the requirements of SCC 30.63A.710 and applicable sections of Snohomish County EDDS Chapter 5. Additional separation requirements may be set forth in sections on specific BMPs in this volume.

4.3.2 Berms

Berms shall be constructed in accordance with Snohomish County EDDS Chapter 5-10.

4.4 Facility Liners

Liners are intended to reduce the likelihood that pollutants in stormwater will reach ground water when runoff treatment facilities are constructed. In addition to groundwater protection considerations, some facility types require permanent water for proper functioning. An example is the first cell of a wetpond.

Treatment liners amend the soil with materials that treat stormwater before it reaches more freely draining soils. They have slow rates of infiltration, generally less than 2.4 inches per hour (1.7 x 10^{-3} cm/s), but not as slow as low permeability liners. Treatment liners may use in-place native soils or imported soils.

Low permeability liners reduce infiltration to a very slow rate, generally less than 0.02 inches per hour $(1.4 \times 10^{-5} \text{ cm/s})$. These types of liners should be used for industrial or commercial sites with a potential for high pollutant loading in the stormwater runoff. Low permeability liners may be fashioned from compacted till, clay, geomembrane, or concrete. Till liners are preferred because of their general resilience and ease of maintenance.

The appropriate liner for a facility shall be selected in accordance with the information below.

4.4.1 General Design Criteria

Liners shall be evenly placed over the bottom and/or sides of the treatment area of the facility. Areas above the treatment volume that are required to pass flows greater than the water quality treatment flow (or volume) need not be lined. However, the lining must be extended to the top of the interior side slope and anchored if it cannot be permanently secured by other means.

Materials and methods shall conform to Snohomish County EDDS Chapter 5 and the Washington State Department of Transportation (WSDOT) Standard Specifications.

Table 5.2 shows requirements for the type of liner to be used with various runoff treatment facilities.

Table 5.2 – Lining 7	Types Recommended for Runor	ff Treatment Facilities
WQ Facility	Area to be Lined	Type of Liner Recommended
Presettling basin	Bottom and sides	Low permeability liner or Treatment liner (If the basin will intercept the seasonal high ground water table, a treatment liner is recommended.)
Wetpond	First cell: bottom and sides to WQ design water surface	Low permeability liner or Treatment liner (If the wet pond will intercept the seasonal high ground water table, a treatment liner is recommended.)
	Second cell: bottom and sides to WQ design water surface	Treatment liner
Combined detention/WQ facility	First cell: bottom and sides to WQ design water surface	Low permeability liner or Treatment liner (If the facility will intercept the seasonal high ground water table a treatment liner is recommended.)
	Second cell: bottom and sides to WQ design water surface	Treatment liner
Stormwater wetland	Bottom and sides, both cells	Low permeability liner (If the facility will intercept the seasonal high ground water table, a treatment liner is recommended.)
Sand filtration basin	Basin sides only	Treatment liner
Sand filter vault	Not applicable	No liner needed
Linear sand filter	Not applicable if in vault	No liner needed
	Bottom and sides of presettling cell if not in vault	Low permeability or treatment liner
Media filter (in vault)	Not applicable	No liner needed
Wet vault	Not applicable	No liner needed

4.4.2 Design Criteria for Treatment Liners

- Treatment liners shall consist of two feet of soil with a minimum organic content of 5% AND a minimum cation exchange capacity (CEC) of 5 milliequivalents/100 grams.
- One sample per 1,000 square feet of facility area shall be tested. Each sample shall be a composite of subsamples taken throughout the depth of the treatment layer (usually two to six feet below the expected facility invert).
- Organic content shall be measured on a dry weight basis using ASTM D2974 07 Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils.

- Cation exchange capacity (CEC) shall be tested using USEPA Method 9081, Cation Exchange Capacity of Soils (Sodium Acetate).
- Certification by a soils testing laboratory that imported soil meets the organic content and CEC criteria above shall be provided to Snohomish County.
- Animal manures used in treatment soil layers must be sterilized because of potential for bacterial contamination of the groundwater.
- If a treatment liner will be below the seasonal high water level, the pollutant removal performance of the liner must be evaluated by a geotechnical or groundwater specialist and found to be as protective as if the liner were above the level of the groundwater.
- If the soil in the liner is not the native soil or the soil has very low permeability, the side walls must be lined with at least 18 inches of treatment soil to prevent untreated seepage.

4.4.3 Design Criteria for Low Permeability Liner Options

This section presents the design criteria for each of the following four low permeability liner options: compacted till liners, compacted clay liners, geomembrane liners, and concrete liners.

General

- Where grass must be planted over a low permeability liner per the facility design, a minimum of 6 inches of good topsoil or compost-amended native soil (2 inches compost tilled into 6 inches of native till soil) must be placed over the liner in the area to be planted. Twelve inches of cover is preferred.
- A low permeability liner shall not be used if seasonal high groundwater is likely to contact
 the liner, unless liner buoyancy is evaluated by a geotechnical engineer and addressed in the
 design as stipulated by that engineer.
- Where grass must be planted over a low permeability liner per the facility design, a minimum of 6 inches of topsoil or compost-amended soil shall be placed over the liner in the area to be planted.

Compacted Till Liners

• Soils for compacted till liners shall meet the following size gradation:

Sieve Size	Minimum Percent Passing
6 inch	100%
4 inch	90%
#4	70% - 100%
#200	20%

- Soil should be placed in 6-inch lifts.
- Soil shall be compacted to 95% minimum dry density, modified proctor method (ASTM D-1557).
- Liner thickness shall be a minimum of 18 inches after compaction.

• A different depth and density sufficient to retard the infiltration rate to 2.4 x 10⁻⁵ inches per minute (1 x 10⁻⁶ cm/s) may also be used.

Compacted Clay Liners

- Clay shall be compacted to 95% minimum dry density, modified proctor method (ASTM D-1557).
- Clay liner thickness after compaction shall be a minimum of 12 inches.
- A different depth and density sufficient to retard the infiltration rate to 2.4×10^{-5} inches per minute $(1 \times 10^{-6} \text{ cm/s})$ may also be used.
- The slope of clay liners must be restricted to 3H: IV for all areas requiring soil cover; otherwise, the soil layer must be stabilized by another method so that soil slippage into the facility does not occur. Any alternative soil stabilization method must take maintenance access into consideration.

Geomembrane Liners

- Geomembrane liners shall be ultraviolet (UV) light resistant and have a minimum thickness of 30 mils. A thickness of 40 mils shall be used in areas of maintenance access or where heavy machinery must be operated over the membrane.
- Geomembranes shall be bedded according to the manufacturer's recommendations.
- Geomembrane liners shall be installed so that they can be covered with 12 inches of top dressing forming the bottom and sides of the facility. Top dressing shall consist of 6 inches of crushed rock covered with 6 inches of native soil. The rock layer is to mark the location of the liner for future maintenance operations. As an alternative to crushed rock, 12 inches of native soil may be used if orange plastic "safety fencing" or another highly-visible, continuous marker is embedded 6 inches above the membrane.
- Geomembrane liners shall not be used on slopes steeper than 5H:1V to prevent the top dressing material from slipping. Textured liners may be used on slopes up to 3H:1V upon recommendation by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.

Concrete Liners

- Portland cement liners are allowed irrespective of facility size, and shotcrete may be used on slopes.
- Specifications must be developed by a professional engineer who certifies the liner against cracking or losing water retention ability under expected conditions of operation, including facility maintenance operations.
- Asphalt concrete may not be used for liners due to its permeability to many organic pollutants.
- If grass is to be grown over a concrete liner, slopes must be no steeper than 5H: IV to prevent the top dressing material from slipping.

4.5 Hydraulic Structures

4.5.1 Flow Splitter Designs

Many water quality (WQ) facilities can be designed as flow-through or on-line systems with flows above the WQ design flow or volume simply passing through the facility at a lower pollutant removal efficiency. However, it is sometimes desirable to restrict flows to WQ treatment facilities and bypass the remaining higher flows around them through off-line facilities. This can be accomplished by splitting flows in excess of the WQ design flow upstream of the facility and diverting higher flows to a bypass pipe or channel. The bypass typically enters a detention pond or the downstream receiving drainage system, depending on flow control requirements. In most cases, it is a designer's choice whether WQ facilities are designed as on-line or off-line; an exception is oil/water separators, which must be designed off-line.

A crucial factor in designing flow splitters is to ensure that low flows are delivered to the treatment facility up to the WQ design flow rate. Above this rate, additional flows are diverted to the bypass system with minimal increase in head at the flow splitter structure to avoid surcharging the WQ facility under high flow conditions.

Flow splitters are typically manholes or vaults with concrete baffles. In place of baffles, the splitter mechanism may be a half tee section with a solid top and an orifice in the bottom of the tee section. A full tee option may also be used as described below in the "General Design Criteria." Standard details for flow splitters are shown in Snohomish County EDDS Standard Drawings 5-250A and 5-250B.

General Design Criteria

- A flow splitter must be designed to deliver the WQ design flow rate specified in this volume to the WQ treatment facility. For the basic size sand filter, which is sized based on volume, use the WQ design flow rate to design the splitter. For the large sand filter, use the 2-year flow rate or the flow rate that corresponds with treating 95 percent of the runoff volume of a long-term time series predicted by an approved continuous runoff hydrologic model.
- The top of the weir must be located at the water surface for the design flow. Remaining flows enter the bypass line. Flows modeled using a continuous simulation model should use 15-minute time steps, if available. Otherwise use 1-hour time steps.
- The maximum head must be minimized for flow in excess of the WQ design flow. Specifically, flow to the WQ facility at the 100-year water surface must not increase the design WQ flow by more than 10%.
- As an alternative to using a solid top plate in Snohomish County EDDS Standard Drawing 5-270C, a full tee section may be used with the top of the tee at the 100-year water surface. This alternative would route emergency overflows (if the overflow pipe were plugged) through the WQ facility rather than back up from the manhole.
- Special applications, such as roads, may require the use of a modified flow splitter. The baffle wall may be fitted with a notch and adjustable weir plate to proportion runoff volumes other than high flows.

• For ponding facilities, back water effects must be included in designing the height of the standpipe in the manhole.

Materials

- Materials shall be in accordance with Snohomish County EDDS Chapter 5.
- The splitter baffle may be installed in a Type 2 manhole or vault.
- The baffle wall must be made of reinforced concrete or another suitable material resistant to corrosion, and have a minimum 4-inch thickness. The minimum clearance between the top of the baffle wall and the bottom of the manhole cover must be 4 feet; otherwise, dual access points should be provided.

4.5.2 Flow Spreading Options

Flow spreaders function to uniformly spread flows across the inflow portion of water quality facilities (e.g., sand filter, biofiltration swale, or filter strip). There are two flow spreader options presented in this section:

- Option 1 Concrete sump box be used for spreading flows that are concentrated or unconcentrated.
- Option 2 Interrupted curb used only for flows that are already unconcentrated and enter a filter strip or continuous inflow biofiltration swale.

General Design Criteria

- See Snohomish County EDDS Chapter 5-05M.
- Where flow enters the flow spreader through a pipe, it is recommended that the pipe be submerged to the extent practical to dissipate energy as much as possible.
- For higher inflows (greater than 5 cfs for the 100-yr storm), a Type 1 catch basin should be positioned in the spreader and the inflow pipe should enter the catch basin with flows exiting through the top grate. The top of the grate should be lower than the level spreader plate, or if a notched spreader is used, lower than the bottom of the v-notches.

Option 1 -- Concrete Sump Box (See Figure 5.1)

- The wall of the downstream side of a rectangular concrete sump box must extend a minimum of 2 inches above the treatment bed. This serves as a weir to spread the flows uniformly across the bed.
- The downstream wall of a sump box must have "wing walls" at both ends. Side walls and returns must be slightly higher than the weir so that erosion of the side slope is minimized.
- Concrete for a sump box can be either cast-in-place or precast, but the bottom of the sump must be reinforced with wire mesh for cast-in-place sumps.
- Sump boxes must be placed over bases that consists of 4 inches of crushed rock, 5/8-inch minus to help assure the sump remains level.

Option 2 -- Interrupted Curb (No Figure)

Interrupted curbs are sections of curb placed to have gaps spaced at regular intervals along the total width (or length, depending on facility) of the treatment area. At a minimum, gaps must be every 6 feet to allow distribution of flows into the treatment facility before they become too concentrated. The opening must be a minimum of 11 inches. As a general rule, no opening should discharge more than 10 percent of the overall flow entering the facility.

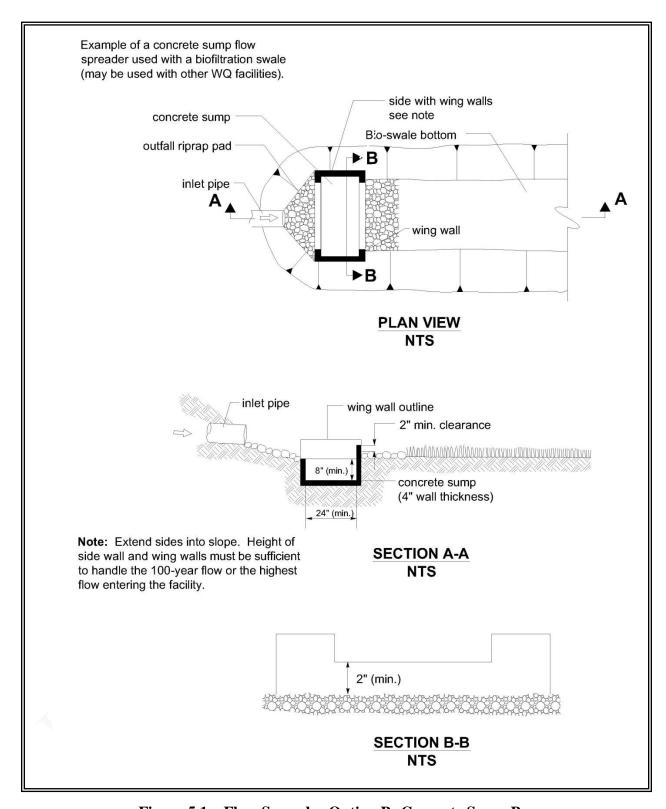


Figure 5.1 – Flow Spreader Option B: Concrete Sump Box

4.5.3 Outfall Systems

Properly designed outfalls are critical to reducing the chance of adverse impacts as the result of concentrated discharges from pipe systems and culverts, both onsite and downstream. Outfall systems include rock splash pads, flow dispersal trenches, gabion or other energy dissipaters, and tightline systems. A tightline system is typically a continuous length of pipe used to convey flows down a steep or sensitive slope with appropriate energy dissipation at the discharge end.

General Design Criteria

Provided below are general design criteria for both Outfall Features and Tightline Systems.

Outfall Features

At a minimum, all outfalls must be provided with a rock splash pad (See EDDS Standard Drawing 5-060) except as specified below:

- The flow dispersion systems shown in Snohomish County EDDS Standard Drawings 5-070 through 5-085 should only be used when both criteria below are met:
 - 1. An outfall is necessary to disperse concentrated flows across uplands where no conveyance system exists and the natural (existing) discharge is unconcentrated; and
 - 2. The 100-year peak discharge rate is less than or equal to 0.5 cfs.
- For freshwater outfalls with a design velocity greater than 10 fps, a gabion dissipater or engineered energy dissipater may be required. See Snohomish County EDDS Chapter 5-05M for engineering design information and details for energy dissipation.
- Tightline systems may be needed to prevent aggravation or creation of a downstream erosion problem.
- In marine waters, rock splash pads and gabion structures are not recommended due to corrosion and destruction of the structure, particularly in high energy environments. Diffuser Tee structures (see Snohomish County EDDS Standard Drawing 5-085, are also not generally recommended in or above the intertidal zone. They may be acceptable in low bank or rock shoreline locations. Stilling basins or bubble-up structures are acceptable. Generally, tightlines trenched to extreme low water or dissipation of the discharge energy above the ordinary high water line are preferred. Outfalls below extreme low water may still need an energy dissipation device (e.g., a tee structure) to prevent nearby erosion.
- Energy dissipation requirements are set forth in Snohomish County EDDS Chapter 5-05M, including stilling basins, drop pools, hydraulic jump basins, baffled aprons, and bucket aprons, are required for outfalls with design velocity greater than 20 fps. These should be designed using published or commonly known techniques found in such references as *Hydraulic Design of Energy Dissipaters for Culverts and Channels*, published by the Federal Highway Administration of the United States Department of Transportation; *Open Channel Flow*, by V.T. Chow; *Hydraulic Design of Stilling Basins and Energy Dissipaters*, EM 25, Bureau of Reclamation (1978); and other publications, such as those prepared by the Natural Resource Conservation Service.

- Alternate mechanisms may be used, such as bubble-up structures that eventually drain and structures fitted with reinforced concrete posts. If any alternate mechanisms are to be considered, they should be designed using sound hydraulic principles and consideration of ease of construction and maintenance.
- Mechanisms that reduce velocity prior to discharge from an outfall are encouraged. Some of
 these are drop manholes and rapid expansion into pipes of much larger size. Other discharge
 end features may be used to dissipate the discharge energy. An example of an end feature is
 the use of a Diffuser Tee with holes in the front half, as shown in Snohomish County EDDS
 Standard Drawing 5-085.
- New pipe outfalls can provide an opportunity for low-cost fish habitat improvements. For example, an alcove of low-velocity water can be created by constructing the pipe outfall and associated energy dissipater back from the stream edge and digging a channel, over-widened to the upstream side, from the outfall to the stream (as shown in Figure 5.2). Overwintering juvenile and migrating adult salmonids may use the alcove as shelter during high flows. Potential habitat improvements should be discussed with the Washington Department of Fish and Wildlife biologist prior to inclusion in design.
- Bank stabilization, bioengineering and habitat features may be required for disturbed areas.
- Outfall structures should be located where they minimize impacts to fish, shellfish, and their habitats.
- One caution to note is that the in-stream sample gabion mattress energy dissipater may not be acceptable within the ordinary high water mark of fish-bearing waters or where gabions will be subject to abrasion from upstream channel sediments. A four-sided gabion basket located outside the ordinary high water mark should be considered for these applications.
- Stormwater outfalls submerged in a marine environment can be subject to plugging due to biological growth and shifting debris and sediments. Therefore, unless intensive maintenance is regularly performed, they may not meet their designed function.

Tightline Systems

- Outfall tightlines may be installed in trenches with standard bedding on slopes up to 20%. In order to minimize disturbance to slopes greater than 20%, it is recommended that tightlines be placed at grade with proper pipe anchorage and support.
- Except as indicated above, tightlines or conveyances that traverse the marine intertidal zone and connect to outfalls must be buried to a depth sufficient to avoid exposure of the line during storm events or future changes in beach elevation. If non-native material is used to bed the tightline, such material shall be covered with at least 3 feet of native bed material or equivalent.

- High density polyethylene pipe (HDPP) tightlines must be designed to address the material limitations, particularly thermal expansion and contraction and pressure design, as specified by the manufacturer. The coefficient of thermal expansion and contraction for solid wall polyethylene pipe (SWPE) is on the order of 0.001 inch per foot per Fahrenheit degree. Sliding sleeve connections must be used to address this thermal expansion and contraction. These sleeve connections consist of a section of the appropriate length of the next larger size diameter of pipe into which the outfall pipe is fitted. These sleeve connections must be located as close to the discharge end of the outfall system as is practical.
- Due to the ability of HDPP tightlines to transmit flows of very high energy, special consideration for energy dissipation must be made. See Snohomish County EDDS Chapter 5-05M for energy dissipation requirements.

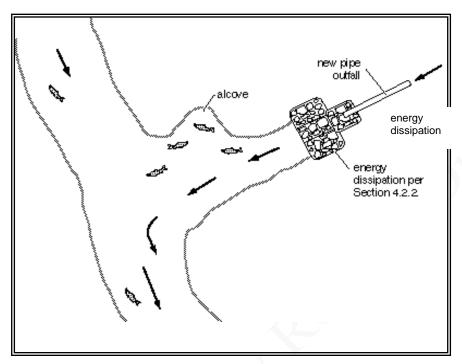


Figure 5.2 – Fish Habitat Improvement at New Outfalls

4.6 Maintenance Requirements Standards for Drainage Stormwater Facilities and Catch Basins

4.6.1 Purpose

The purpose of this chapter is to set forth maintenance <u>requirements standards</u> for <u>different components of drainagestormwater</u> facilities <u>and including</u> catch basins. The <u>se-requirements include maintenance</u> standards <u>giveprovidedn in Volume VI -Stormwater Facility Maintenance</u>. <u>For each which match</u> specific facility components and features <u>with the</u> approved uniform maintenance <u>procedures standards are listed</u>.

The facility-specific maintenance <u>requirements</u> <u>standards contained in this section</u> are intended to be conditions for determining if maintenance actions are required, as identified through inspection. The following definitions apply to maintenance described in this chapter <u>and Volume VI.</u>

"DrainageStormwater facility," for the purposes of this chapter and Volume VI, means a catch basin or stormwater flow control or treatment facility, including components and access, described in Tables 5.31 through 27 in Volume VI of this chapter manual.

-"Maintenance" for this chapter <u>and Volume VI</u> shall be used to mean regular maintenance, repair or replacement actions. The maintenance standards are not intended to be measures of a facility's required condition at all times between inspections. In other words, if these conditions are exceeded at any time between inspections and/or maintenance, this does not automatically constitute a violation of these standards.

4.6.2 Applicability

This chapter applies to drainagestormwater facilities identified in Table 5.3 of this chapter that are owned or operated by Snohomish County, catch basins owned or operated by the County, and such drainagestormwater facilities and catch basins owned by other entities or individuals.

4.6.3 Enforcement

Chapter 7.54 Snohomish County Code (SCC) requires any owner or operator of a drainage stormwater facility described in this chapter to maintain the facility in accordance with the requirements and standards set forth in this chapter and Volume VI.

4.6.4 Tracking Maintenance and Repair Costs

Chapter 7.54 Snohomish County Code (SCC) requires that property owners and operators of stormwater facilities to keep records of their maintenance actions for their drainage stormwater facilities. In addition, Snohomish County requests that these owners and operators to of drainage facilities track the cost of maintenance and repairs and provide these costs tothat information to the County. The However, the request for cost information is not a regulatory requirement. The information will be used by the County to estimate general maintenance and repair cost information, and order to provide that information useful data to members of the public, including homeowners associations, who may need to perform such work and estimate costsplan and budget for maintenance services. The County does not intend to provide cost information that can be traced to a specific facility.

4.6.5 Drainage Stormwater Facility Maintenance Schedule

A) Maintenance actions to be completed within thirty days of the date of notice

- 1. 1)—When a County-initiated inspection of a flow control structure finds that the hydraulic function of the structure is significantly impaired, the owner or operator shall have thirty days from the date of the notice issued by the County in which to complete maintenance actions required by the notice.
- 2 2)—If, after thirty days, the required maintenance actions have not been completed, the owner or operator will be in violation of County code SCC and will be subject to enforcement actions by the County. In such cases, the County may, at its option, perform the necessary maintenance actions, in which case the owner or operator will be charged for all costs the County incurs for performing these maintenance actions.

B) Maintenance actions to be completed within one year of the date of notice

- 1. 1)—In addition to the requirements of section 4.6.5A, when a County-initiated inspection of a drainage stormwater facility identifies one or more conditions for any component listed in Table 5.3tables 1 through 27 of Volume VI for which maintenance is needed, and for which the necessary maintenance actions are estimated to cost less than \$25,000, the owner or operator has one year from the date of the notice issued by the County in which to complete maintenance actions required by the notice. If maintenance of a flow control structure is required under section 4.6.5A, the cost of those maintenance actions shall be considered part of the total maintenance cost for the entire drainage stormwater facility.
- 2 2)—The owner or operator is responsible for obtaining all required permits and permissions before starting work.
- 3 3)—If, after one year from the date of the notice, the required maintenance actions have not been completed, the owner or operator will be subject to enforcement action by the County. In such cases, the County may, at its option, perform the necessary maintenance actions, in which case the owner or operator will be charged for all costs the County incurs for performing these maintenance actions.
- 4)—With the exception of work described in 4.6.5A and 4.6.5D, maintenance actions may not be allowed <u>during</u> the period from October 1 to April 30 in order to ensure that downstream property and stream corridors will not be subject to flooding, habitat degradation, or pollutant contamination as a result of these actions.
- 5) Depending on the scope of work and seasonal conditions, the County reserves the right to require the owner or operator to complete necessary maintenance actions in the first year during the period from May 1 to September 30.

C) Maintenance actions to be completed within two years of the date of notice

1. 1)—In addition to the requirements of section 4.6.5A, when a County-initiated inspection of a drainage stormwater facility identifies one or more conditions for any component listed in Table 5.3tables 1 through 27 of Volume VI for which maintenance is needed required, and for which the necessary maintenance actions are estimated to cost \$25,000 or more, the owner or operator has two years from the date of the notice issued by the County in which to complete those required maintenance actions required by the

- notice as well as any other actions needed to produce the expected results in Table 5.3. If maintenance of a flow control structure is required under section 4.6.5A, the cost of those maintenance actions shall <u>be</u> considered part of the total maintenance cost for the entire <u>drainage</u> stormwater facility.
- 2 2)—The owner or operator shall be responsible for acquiring all needed permits and permissions before commencing work.
- 3 3)—If, after two years from the date of the notice, the required maintenance actions have not been completed, the owner or operator will be subject to enforcement action by the County. In such cases, the County may, at its option, perform the necessary maintenance actions, in which case the owner or operator will be charged for all costs the County incurs for performing these maintenance actions.
- 4 4)—With the exception of work described in 4.6.5A and 4.6.5D, maintenance actions may not be allowed <u>during</u> the period from October 1 to April 30 in order to ensure that downstream property and stream corridors will not be subject to flooding, habitat degradation, or pollutant contamination as a result of these actions.
- 5 Depending on the scope of work and seasonal conditions, the County reserves the right to require the owner or operator to complete necessary maintenance actions in the first year during the period from May 1 to September 30.

D) Emergency orders

1)—In addition to any requirements described above, and in accordance with the provisions of Chapter 30.85 SCC, if the County determines that a condition exists at a drainage stormwater facility that endangers public or private property, creates an immediate hazard, creates a violation of critical areas provisions or surface water protection, or threatens the health and safety of the occupants of any premises or members of the public, the County may issue an emergency order. Upon issuance of an emergency order, the owner or operator of the drainage stormwater facility shall remedy the condition immediately.

4.6.6 Maintenance Standards

Maintenance standards are set forth in <u>Tables 1 through 27 of this manual</u> (Stormwater Facility Maintenance).- <u>Below Table 5.3 lists all the stormwater facilities in that are described in Volume VI-with maintenance standards</u>.

Table 5.3 – <u>Stormwater Facilities with Maintenance Standards</u> (See Volume 6VI for Maintenance Standards)

No. 1 .	Catch Basins
No. 2 .	Conveyance Storm Pipes
No. 3 .	Debris Barriers (e.g., Trash Racks)
No. 4 C	Control Structure/Flow Restrictors
No. 5 .	Facility Discharge Points
No. 6 .	Energy Dissipaters
No. 7 .	Detention Ponds
No. 8	-Underground Detention Pipes/Tanks
No. 9	-Infiltration Facilities
No. 10	-Wetponds
No. 11	-Wetvaults
No. 12	-Bioretention Systems
No. 13	-Typical Biofiltration Swales
No. 14	-Wet Biofiltration Swales
No. 15	-Compost Amended Vegetated Filter Strip (CAVFS)
No. 16	-Media Filter Drain
No. 17	-Filter Strips
No. 18	-Sand Filters (above ground/open)
No. 19	-Sand Filters (below ground/enclosed)
No. 20	-Permeable Pavement
No. 21	Vegetated Roofs
No. 22	-Media Filter Cartridge Filters
No. 23	-Hydrodynamic Separators
No. 24	-API Baffle Oil/Water Separators
No. 24	-Coalescing Plate Oil/Water Separators
No. 26	-Catchbasin Inserts
No. 27	-Access Gates
No. 28	-Access Roads

No. 1 Detention Ponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash & Debris	Function of facility is impaired by or likely to be impaired by trash and debris.	Trash and debris is removed.
	Vegetation	Function of facility is impaired by vegetation.	Vegetation is removed or managed to restore proper function of facility.
			Use of herbicides shall be in accordance with applicable regulations.
	Contaminants and Pollution	Any evidence of oil, gasoline, contaminants or other pollutants	Contaminants or pollutants are removed
		Note: Coordinate removal/cleanup with local and/or state water quality response agency.	
	Beaver Dams	Dam results in change or function of the facility:	Facility is returned to design function. Note: Contact Snohomish County Surface Water Management if removal of beavers is contemplated.
	Insects	When insects such as wasps and hornets interfere with maintenance activities.	Insects are destroyed or removed from site. Use of pesticides shall be in accordance with applicable regulations
	Tree Growth and Hazard Trees	Function of facility is impaired by trees. Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements). If trees are not interfering with access or maintenance, do not remove	Trees are removed or managed to restore proper function of facility. Trees do not hinder maintenance activities. Hazard trees are identified and those that pose an imminent danger are removed.
		Hazard trees (i.e., dead, diseased, or dying trees) need to be identified Note: A certified Arborist may be needed to determine health of trees or removal requirements.	
	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion.	Slopes are stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.
General	Liner (If Applicable)	Liner is visible and has more than three 1/4 inch holes in it.	Liner is repaired or replaced. Liner is fully covered.
Berms	Settling	Any part of a berm which has settled at least 4 inches lower than the design elevation.	Berm is repaired and restored to the design elevation.
		If settlement is apparent, measure berm to determine amount of settlement.	
		Settling can be an indication of more severe problems with the berm or outlet works. Note: A licensed civil engineer may be needed to determine the cause of the settlement.	

No. 1 Detention Ponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
	Erosion	Any erosion observed on a compacted structural berm embankment. Note: A licensed civil engineer may be needed to inspect, evaluate and recommend a repair plan.	Slopes should be stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.
	Piping	Discernable water flow through a compacted structural berm. Ongoing erosion with potential for erosion to continue.	Piping climinated. Erosion potential resolved.
		Tree growth on a compacted structural berm over 4 feet in height may lead to piping through the berm which could lead to failure of the berm.	
		Evidence of rodent holes in berm, and/or water piping through berm via rodent holes	
		Note: A geotechnical engineer may be needed to inspect and evaluate condition and recommend repair of condition.	
Storage Area	Sediment	Accumulated sediment that exceeds 10% of the designed pond depth unless otherwise specified or affects inletting or outletting condition of the facility.	Sediment cleaned out to designed pond shape and depth; pond reseded if necessary to control erosion.
Emergency Overflow/ Spillway	Tree Growth	Tree growth on emergency spillways creates blockage problems and may cause failure of the berm due to uncontrolled overtopping.	Trees should be removed. If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored.
			Note: A licensed civil engineer may be needed to determine proper berm/spillway restoration.
	Rock Armoring	Rock layer on subgrade is less than 1.0 feet deep and/or subgrade is exposed	Rocks and pad depth are restored to a minimum depth of 1.0 feet.
	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion.	Slopes are stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.

NOTE: The above maintenance standards also apply to naturally-occurring closed depressions used to meet the flow control requirements set forth in SCC 30.63A.550.

No. 2 Infiltration Facilities

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash & Debris	Function of facility is impaired by or likely to be impaired by trash and debris.	Trash and debris is removed.
	Vegetation	Function of facility is impaired by vegetation.	Vegetation is removed or managed to restore proper function of facility. Use of herbicides shall be
			in accordance with applicable regulations.
	Contaminants and Pollution	Any evidence of oil, gasoline, contaminants or other pollutants	Contaminants or pollutants are removed
		Note: Coordinate removal/eleanup with local and/or state water quality response agency.	7
	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion.	Slopes are stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.
Storage Area	Sediment	Water ponding in infiltration pond after rainfall ceases and appropriate time allowed for infiltration. (A percolation test pit or test of facility indicates facility is only working at 90% of its designed capabilities. If two inches or more sediment is present, remove).	Sediment is removed and/or facility is cleaned so that infiltration system works according to design.
Filter Bags (if applicable)	Sediment and Debris	Sediment and debris fill bag more than 1/2 full.	Filter bag is replaced or system is redesigned.
Rock Filters	Sediment and Debris	By visual inspection, little or no water flows through filter during heavy rain storms.	Gravel in rock filter is replaced.
Side Slopes of Pond	Erosion	See "Detention Ponds" (No. 1).	See "Detention Ponds" (No. 1).
Berms	Settling	Any part of a berm which has settled at least 4 inches lower than the design elevation. If settlement is apparent, measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works. Note: A licensed civil engineer may be needed to determine the cause of the settlement.	Berm is repaired and restored to the design elevation.
	Erosion	Any erosion observed on a compacted structural berm embankment. Note: A licensed civil engineer may be needed to inspect, evaluate and recommend a repair plan.	Slopes should be stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.

No. 2 Infiltration Facilities

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
	Piping	Discernable water flow through a compacted structural berm. Ongoing crosion with potential for crosion to continue. Tree growth on a compacted structural berm over 4 feet in height may lead to piping through the berm which could lead to failure of the berm. Evidence of rodent holes in berm, and/or water piping through berm via rodent holes Note: A geotechnical engineer may be needed to inspect and evaluate condition and	Piping eliminated. Erosion potential resolved.
T.	T. C. 1	recommend repair of condition.	T 1 111
Emergency Overflow Spillway	Tree Growth	Tree growth on emergency spillways creates blockage problems and may cause failure of the berm due to uncontrolled overtopping.	Trees should be removed. If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored. Note: A licensed civil engineer may be needed to determine proper berm/spillway restoration.
	Rock Armoring	Rock layer on subgrade is less than 1.0 feet deep and/or subgrade is exposed	Rocks and pad depth are restored to a minimum depth of 1.0 feet.
	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion.	Slopes are stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.
Pre-settling Ponds and Vaults	Facility or sump filled with Sediment and/or debris	The settling area or sump contains sediment/debris up to a depth of either 6 inches or the sedimentation design depth.	Sediment/debris is removed.

No. 3 Underground Detention Pipes/Tanks

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Storage Area	Plugged Air Vents	One half of the cross section of a vent is blocked at any point or the vent is damaged.	Vents open and functioning.
	Debris and Sediment	The average sediment depth measured at multiple locations exceeds 10% of the detention pipe diameter (or the depth of the storage area) or the sediment depth measured at any single point exceeds 15% of the pipe diameter. (Example: The sediment depth in a 60 inch	All sediment, debris, and organic matter removed from storage area.
		diameter detention pipe is measured at three locations. The sediment would need to be removed if the average depth of the three measurements is at least 6 inches or if the depth of any single measurement is at least 9 inches.	
	Joints Between Tank/Pipe Section	Any openings or voids at section joint allowing material to seep into or water to leak out of facility.	All joints between tank/pipe sections are sealed.
		Note: This may need an engineering analysis to assess the structural stability.	
	Tank or Pipe Bent Out of Shape	Any part of tank/pipe is bent out of shape more than 10% of its design shape.	Tank/pipe section is repaired or replaced to
		Note: This may need an engineering analysis to assess the structural stability.	design.
	Tank/Pipe Material	Any visible holes or cracks wider than a quarter of an inch or evidence of material seeping into or water leaking out of pipe wall, or qualified maintenance or inspection personnel determine that tank/pipe is not structurally sound.	Tank/pipe is repaired or replaced to design specifications and is structurally sound.
Access Hole	Cover Not in Place	Cover is missing or only partially in place. Any open manhole requires maintenance.	Manhole is closed.
	Locking Mechanism Not Working	Locking mechanism cannot be opened or lock bolts cannot be removed by one maintenance person with proper hand tools.	Mechanism or lock bolts open with proper hand tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure with proper hand tools. Intent is to keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person with proper hand tools.
	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, eracked/broken rungs, misalignment, rungs not securely attached to structure wall, rust, or eracks.	Ladder meets design standards and allows maintenance person safe access.
Catch Basins	See "Catch Basins" (No. 5)	See "Catch Basins" (No. 5).	See "Catch Basins" (No. 5).
Standpipe, Cleanout Gate, Orifice Plate	Obstructions, Damaged, or Missing	See "Control Structure/Flow Restrictors" (No. 4)	See "Control Structure/Flow Restrictors" (No. 4)

No. 4 Control Structure/Flow Restrictors

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Standpipe	Obstructions	Any material blocking (or having the potential of blocking) the pipe overflow.	Pipe is free of all obstructions and works as designed.
	Structural Damage	Structure is not securely attached to manhole wall.	Structure is securely attached to wall and outlet pipe.
		Structure is not in upright position (allow up to 10% from plumb).	Structure is in correct position.
		Connections to outlet pipe are not watertight and show signs of rust.	Connections to outlet pipe are water tight; structure repaired or replaced and works as designed.
		Any holes other than designed holes in the structure.	Structure has no holes other than designed holes.
Cleanout Gate	Damaged or Missing	Cleanout gate is not watertight or is missing.	Gate is watertight and works as designed.
		Gate cannot be moved up and down by one maintenance person.	Gate moves up and down easily and is watertight.
		Chain/rod leading to gate is missing or damaged.	Chain is in place and works as designed.
		Gate is rusted over 50% of its surface area.	Gate is repaired or replaced to meet design standards.
Orifice Plate	Damaged or Missing	Control device is not working properly due to missing, out of place, or bent orifice plate.	Plate is in place and works as designed.
	Obstructions	Any trash, debris, sediment, or vegetation blocking the plate.	Plate is free of all obstructions and works as designed.
Overflow Pipe	Obstructions	Any trash or debris blocking (or having the potential of blocking) the overflow pipe.	Pipe is free of all obstructions and works as designed.
Access Hole	Cover Not in Place	Cover is missing or only partially in place. Any open manhole requires maintenance.	Manhole is closed.
	Locking Mechanism Not Working	Locking mechanism cannot be opened or lock bolts cannot be removed by one maintenance person with proper hand tools.	Mechanism or lock bolts open with proper hand tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure with proper hand tools. Intent is to keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person with proper hand tools.
	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, eracked/broken rungs, misalignment, rungs not securely attached to structure wall, rust, or cracks.	Ladder meets design standards and allows maintenance person safe access.

No. 4 Control Structure/Flow Restrictors

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Catch Basin	See "Catch Basins" (No. 5).	See "Catch Basins" (No. 5).	See "Catch Basins" (No. 5).
	Sediment & Debris	Sediment, trash, vegetation, and/or other debris material exceeds 25% of the catch basin sump depth or is 1 foot below the orifice plate.	Control structure orifice is not blocked. All sediment and debris removed.

No. 5 - Catch Basins

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is performed
General	Sediment & Debris	Sediment, trash, and/or other debris material is located immediately in front of the catch basin opening or is blocking inletting capacity of the basin by more than 10%.	No sediment or debris is located immediately in front of eatch basin or on grate opening.

No. 5 - Catch Basins

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is performed
		Sediment, trash, and/or other debris material (located in the catch basin) exceeds 60 percent of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of six inches clearance from the debris surface to the invert of the lowest pipe.	No sediment or debris is in the eatch basin.
		 Sediment, trash, and/or other debris material located in any inlet or outlet pipe is blocking more than 1/3 of its height. 	 Inlet and outlet pipes are free of sediment and debris.
		Dead animals or vegetation that impair catch basin function or that could generate odors that could cause complaints or dangerous gases (e.g., methane).	No dead animals or vegetation are present within the eatch basin.
	• Structur e Dama ge to Frame and/or Top Slab	 Top slab has holes larger than 2 square inches or cracks wider than 1/4 inch (Intent is to make sure no material is seeping into the catch basin). 	Top slab is free of holes and cracks. No water and/or soil is seeping into the catch basin
		• Frame not sitting flush on top slab, i.e., separation of more than 3/4 inch of the frame from the top slab. Frame not securely attached	 Frame is sitting flush on the riser rings or top slab and firmly attached.
	• Fractur es or Crack s in Basin Walls/ Botto	Cracks wider than 1/2 inch or evidence of soil particles entering the structure through the cracks, or qualified maintenance or inspection personnel determine that the vault is not structurally sound.	• Catch basin is replaced or repaired to design standards.
		Grout fillet has separated or cracked wider than 1/2 inch and longer than 1 foot at the joint of any inlet/outlet pipe or any evidence of soil particles entering catch basin through cracks.	 Pipe is regrouted and secure at basin wall.
	• Settlem ent/ Misali gnme nt	Settlement of misalignment of the catch basin causes a safety, function, or design problem.	• Catch basin is replaced or repaired to design standards.
	• Contam inants and Pollut ion	Any evidence of oil, gasoline, contaminants or other pollutants Note: Coordinate removal/cleanup with local and/or state water quality response agency.	Contaminants or pollutants are removed.
Access Hole Cover	Cover Not in Place	Cover is missing or only partially in place. Any open catch basin requires maintenance.	Catch basin cover is fully in place

No. 5 Catch Basins

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is performed
	• Lockin g Mech anism Not Worki ng	Locking mechanism cannot be opened or lock bolts cannot be removed by one maintenance person with proper hand tools.	Mechanism or lock bolts open with proper hand tools.
	• Cover Diffic ult to Remo ve	One maintenance person cannot remove lid after applying normal lifting pressure with proper hand tools. Intent is keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person with proper hand tools.
Ladder	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, eracked/broken rungs, rungs not securely attached to basin wall, misalignment, rust, cracks, or sharp edges.	Ladder meets design standards and allows maintenance person safe access.
Metal Grates (If Applicable)	Trash and Debris	Trash and debris that is blocking more than 20% of grate surface inletting capacity.	Grate free of trash and debris.
	• Damag e d or Missi ng.	Grate missing or broken member(s) of the grate.	 Grate is in place and meets design standards.

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No. 6 Debris Barriers (e.g., Trash Racks)

Maintenance Components	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and Debris	Trash or debris that is plugging more than 20% of the openings in the barrier.	Barrier cleared to design flow capacity.
Metal	Damaged/ Missing Bars.	Bars are bent out of shape more than 3 inches.	Bars in place with no bends more than 3/4 inch.
		Bars are missing or entire barrier missing.	 Bars in place according to design.
		 Bars are loose and rust is causing 50% deterioration to any part of barrier. 	 Barrier replaced or repaired to design standards.
	• Inlet/ Out let Pip e	Debris barrier missing or not attached to pipe	Barrier firmly attached to pipe

No. 7 Energy Dissipaters

Maintenance Components	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Rock Pad	Missing or Moved Rock	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil where pad was originally installed.	Rock pad replaced to design standards.
	• Erosi	 Soil erosion in or adjacent to rock pad. 	 Rock pad replaced to design standards.
Rock Gabion Structures	Wire basket matrix deteriorated or broken	Deterioration determined to be near to breaking. Broken wire results in hole large enough to allow rocks to protrude out of basket	Rewire area of concern or replace basket and/or rocks as necessary
	• Wire bas ket mis alig ned	Baskets have shifted and no longer providing full energy dissipations or may be prone to tipping or collapse	Realign or relocate as necessary to meet design intent
Dispersion Trench	Perforated Pipe Plugged with Sediment	Accumulated sediment that exceeds 20% of the design depth or over 1/3 of perforations in pipe are plugged.	Pipe cleaned/flushed so that it matches design.
	• Not Dis char ging Wat er Pro perl	Water is discharging at a few eoncentrated points along the top of the trench rather than flowing uniformly along the entire length of trench lip.	• Trench redesigned or rebuilt to standards.
	"Di strib utor " Cat eh Basi n Ove	Water is observed or reported to be flowing out of top of basin during any storm less than the design storm.	■ Facility rebuilt or redesigned to standards.
	• Receiving Are a Ove F Satu rate d	Water in receiving area is causing or has potential of causing landslide problems.	No danger of landslides.
Catch Basins	Other Defects	See "Catch Basins" (No. 5).	See "Catch Basins" (No. 5).



No. 8 Typical Biofiltration Swales

Maintenance	Defect or	Condition When Maintenance is Needed	Recommended Maintenance to Correct
Component	Problem		Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits on grass treatment area of the swale. When finished, swale should be level from side to side and drain freely toward outlet. There should be no areas of standing water once inflow has ceased. Reseed any bare spots as needed in loosened, fertile soil.

No. 8 Typical Biofiltration Swales

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
	• Standing Water	When water stands in the swale between storms and does not drain freely.	 Any of the following may apply: remove sediment or trash blockages, improve grade from head to foot of swale, remove clogged check dams, add underdrains or convert to a wet biofiltration swale.
	• Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire swale width.	Level the spreader and clean so that flows are spread evenly over entire swale width.
	• Constant Baseflo w	When small quantities of water continually flow through the swale, even when it has been dry for weeks and an eroded, muddy channel has formed in the swale bottom.	Add a low flow pea gravel drain the length of the swale or by pass the baseflow around the swale.
	Poor Vegetati on Coverag e	When grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom.	Determine why grass growth is poor and correct that condition. Replant with plugs of grass from the upper slope: plant in the swale bottom at 8 inch intervals. Or reseed into loosened, fertile soil.
	• Vegetatio	When the grass becomes excessively tall (greater than 10- inches); when nuisance weeds and other vegetation starts to take over.	Mow vegetation or remove nuisance vegetation so that flow not impeded. Grass should be mowed to a height of 3 to 4 inches. Remove grass elippings.
	• Excessive Shading	Grass growth is poor because sunlight does not reach swale.	If possible, trim back overhanging limbs and remove brushy vegetation on adjacent slopes. In addition, reseed bare spots with shade tolerant grass seed mix and/or replant with plugs of slough sedge or other sedges.
	■ Inlet/Outl	 Inlet/outlet areas clogged with sediment and/or debris. 	Remove material so that there is no clogging or blockage in the inlet and outlet area.
	• Trash and Debris Accumu lation	 Trash and debris accumulated in the bio-swale. 	Remove trash and debris from swale.
	• Erosion/S couring	• Eroded or scoured swale bottom due to flow channelization, or higher flows.	• For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. If bare areas are large, generally greater than 12 inches wide, the swale should be regraded and reseeded. For smaller bare areas, overseed when bare spots are evident, or take plugs of grass from the upper slope and plant in the swale bottom at 8 inch intervals.

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No. 9 Wet Biofiltration Swales

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation	Sediment depth exceeds 2 inches in 10% of the swale treatment area.	Remove sediment deposits in treatment area.
	Water Depth	Water not retained to a depth of about 4 inches during the wet season.	Build up or repair outlet berm so that water is retained in the wet swale.
	Wetland Vegetation	Vegetation becomes sparse and does not provide adequate filtration, OR vegetation is crowded out by very dense clumps of cattail, which do not allow water to flow through the clumps.	Determine cause of lack of vigor of vegetation and correct. Replant as needed with wetland plants. For excessive cattail growth, cut cattail shoots back and compost offsite. Note: normally wetland vegetation does not need to be harvested unless die back is causing oxygen depletion in downstream waters.
	Inlet/Outlet	Inlet/outlet area clogged with sediment and/or debris.	Remove clogging or blockage in the inlet and outlet areas.
	Erosion/Scouring	Swale has eroded or scoured due to flow channelization, or higher flows.	Check design flows to assure swale is large enough to handle flows. Bypass excess flows or enlarge swale. Replant eroded areas with fibrousrooted plants such as Juneus effusus (soft rush) in wet areas or snowberry (Symphoricarpos albus) in dryer areas.

No. 10 - Filter Strips

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits, re-level so slope is even and flows pass evenly through strip. Reseed any bare spots as needed in loosened, fertile soil.
	Vegetation	When the grass becomes excessively tall (greater than 10 inches); when nuisance weeds and/or other vegetation starts to take over.	Mow grass, control nuisance vegetation, such that flow is not impeded. Grass should be mowed to a height between 3-4 inches.
	Erosion/Scouring	Eroded or scoured areas due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. The grass will creep in over the rock in time. If bare areas are large, generally greater than 12 inches wide, the filter strip should be regraded and reseeded. For smaller bare areas, overseed when bare spots are evident.
	Flow spreader	Flow spreader uneven or elogged so that flows are not uniformly distributed through entire filter width.	Level the spreader and clean so that flows are spread evenly over entire filter width.

No. 11 Wetponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Water level	First cell is empty, doesn't hold water.	Line the first cell to maintain water per the original design. Although the second cell may drain, the first cell must remain full to control turbulence of the incoming flow and reduce sediment resuspension.
	Inlet/Outlet Pipe	Inlet/Outlet pipe clogged with sediment and/or debris material.	No clogging or blockage in the inlet and outlet piping.
	Sediment Accumulation in Pond Bottom	Sediment accumulations in pond bottom that exceeds the depth of sediment zone plus 6 inches, usually in the first cell.	Sediment removed from pond bottom.
	Oil Sheen on Water	Prevalent and visible oil sheen.	Oil removed from water using oil absorbent pads or vactor truck. Source of oil located and corrected. If chronic low levels of oil persist, plant wetland plants such as Juncus effusus (soft rush) which can uptake small concentrations of oil.
	Erosion	Erosion of the pond's side slopes and/or scouring of the pond bottom that exceeds 6 inches, or where continued erosion is prevalent.	Slopes stabilized using proper erosion control measures and repair methods.
Berms	Settling	Any part of a berm which has settled at least 4 inches lower than the design elevation. If settlement is apparent, measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works. Note: A licensed civil engineer may be needed to determine the cause of the settlement.	Berm is repaired and restored to the design elevation.
	Internal Berm	Berm dividing cells should be level.	Berm surface is leveled so that water flows evenly over entire length of berm.
(Erosion	Any erosion observed on a compacted structural berm embankment. Note: A licensed civil engineer	Slopes should be stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.
		may be needed to inspect, evaluate and recommend a repair plan.	

No. 11 Wetponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
	Piping	Discernable water flow through a compacted structural berm. Ongoing erosion with potential for erosion to continue.	Piping eliminated. Erosion potential resolved.
		Tree growth on a compacted structural berm over 4 feet in height may lead to piping through the berm which could lead to failure of the berm.	
		Evidence of rodent holes in berm, and/or water piping through berm via rodent holes	
		Note: A geotechnical engineer may be needed to inspect and evaluate condition and recommend repair of condition.	
Emergency Overflow/ Spillway	spillways creates blockage small (base less problems and may cause failure of may be left in p	Trees should be removed. If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored.	
		overtopping.	Note: A licensed civil engineer may be needed to determine proper berm/spillway restoration.
	Rock Armoring	Rock layer on subgrade is less than 1.0 feet deep and/or subgrade is exposed	Rocks and pad depth are restored to a minimum depth of 1.0 feet.
	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion.	Slopes are stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction.

No. 12 Wetvaults

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash/Debris Accumulation	Trash and debris accumulated in vault, pipe or inlet/outlet (includes floatables and non-floatables).	Remove trash and debris from vault.
	Sediment Accumulation	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6 inches.	Remove sediment from vault.
	Damaged Pipes	Inlet/outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
	Access Hole Cover Damaged/Not Working	One maintenance person cannot remove lid after applying normal lifting pressure with proper hand tools.	Cover can be removed and reinstalled by one maintenance person with proper hand tools.
	Ventilation	Ventilation area blocked or plugged.	Blocking material removed or cleared from ventilation area. Specified % of the vault surface area provides ventilation to the vault interior (see design specifications).
	Vault Structure Damage Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2 inch or evidence of soil particles entering the structure through the cracks, or qualified maintenance or inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2 inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4 inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by qualified maintenance or inspection personnel.	Baffles repaired or replaced to specifications.
	Access Ladder Damage	Ladder is corroded or deteriorated, not functioning properly, not attached to structure wall, missing rungs, has cracked/broken rungs and/or is misaligned. Confined space warning sign missing.	Ladder replaced or repaired to specifications, and allows maintenance person safe access. Replace sign warning of confined space entry requirements. Ladder and entry notification complies with OSHA standards.

No. 13 Sand Filters (above ground/open)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Above Ground (open sand filter)	Sediment Accumulation on top layer	Sediment depth exceeds 1/2 inch.	No sediment deposit on top layer of sand filter that would impede permeability of the filter section.
	Trash and Debris Accumulations	Trash and debris accumulated on sand filter bed.	Trash and debris removed from sand filter bed.
	Sediment/ Debris in Clean- Outs	When the clean-outs become fully or partially plugged with sediment and/or debris.	Sediment removed from clean outs.
	Sand Filter Media	Drawdown of water through the sand filter media takes longer than 24 hours, and/or flow through the overflow pipes occurs frequently.	Top several inches of sand are scraped. May require replacement of entire sand filter depth depending on extent of plugging (a sieve analysis is helpful to determine if the lower sand has too high a proportion of fine material).
	Prolonged Flows	Sand is saturated for prolonged periods of time (several weeks) and does not dry out between storms due to continuous base flow or prolonged flows from detention facilities.	Low, continuous flows are limited to a small portion of the facility by using a low wooden divider or slightly depressed sand surface.
	Short Circuiting	When flows become concentrated over one section of the sand filter rather than dispersed.	Flow and percolation of water through sand filter is uniform and dispersed across the entire filter area.
	Erosion Damage to Slopes	Erosion over 2 inches deep where cause of damage is prevalent or potential for continued erosion is evident.	Slopes stabilized using proper erosion control measures.
	Rock Pad Missing or Out of Place	Soil beneath the rock is visible.	Rock pad replaced or rebuilt to design specifications.
	Flow Spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed across sand filter.	Spreader leveled and cleaned so that flows are spread evenly over sand filter.
	Damaged Pipes	Any part of the piping that is crushed or deformed more than 20% or any other failure to the piping.	Pipe repaired or replaced.

No. 14 Sand Filters (below ground/enclosed)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Below Ground Vault.	Sediment Accumulation on Sand Media Section	Sediment depth exceeds 1/2 inch.	No sediment deposits on sand filter section that would impede permeability of the filter section.
	Sediment Accumulation in Presettling Portion of Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6 inches.	No sediment deposits in first chamber of vault.
	Trash/Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault and inlet/outlet piping.
	Sediment/Debris in Drain Pipes/Cleanouts	Sediment, trash, and/or other debris material located in any inlet, outlet, or eleanout pipe is blocking more than 1/3 of its height.	Sediment and debris removed.
	Short Circuiting	When seepage/flow occurs along the vault walls and corners. Sand eroding near inflow area.	Sand filter media section re-laid and compacted along perimeter of vault to form a semi-seal. Erosion protection added to dissipate force of incoming flow and curtail erosion.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
	Access Hole Cover Damaged/Not Working	One maintenance person cannot remove lid after applying normal lifting pressure with proper hand tools.	Cover can be removed and reinstalled by one maintenance person with proper hand tools.
	Ventilation	Ventilation area blocked or plugged	Blocking material removed or cleared from ventilation area. Specified % of the vault surface area provides ventilation to the vault interior (see design specifications).
	Vault Structure Damaged; Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab.	Cracks wider than 1/2 inch or evidence of soil particles entering the structure through the cracks, or qualified maintenance or inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2 inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4 inch at the joint of the inlet/outlet pipe.
	Baffles/Internal walls	Baffles or walls corroding, cracking, warping and/or showing signs of failure as determined by qualified maintenance or inspection personnel.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, has cracked/broken rungs, and/or is misaligned.	Ladder replaced or repaired to specifications, and allows maintenance person safe access.

No. 15 StormfilterTM

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Below Ground Vault	Sediment Accumulation on Media.	Sediment depth exceeds 1/4 inch.	No sediment deposits which would impede permeability of the compost media.
	Sediment Accumulation in Vault	Sediment depth exceeds 6 inches in first chamber.	No sediment deposits in vault bottom of first chamber.
	Trash/Debris Accumulation	Trash and debris accumulated on compost filter bed.	Trash and debris removed from the compost filter bed.
	Sediment/Debris in Drain Pipes/Cleanouts	Sediment, trash, and/or other debris material located in any inlet, outlet, or cleanout pipe is blocking more than 1/3 of its height.	Sediment and debris removed.
	Damaged Pipes	Any part of the pipes that are crushed or damaged due to corrosion and/or settlement.	Pipe repaired and/or replaced.
	Access Hole Cover Damaged/Not Working	One maintenance person cannot remove lid after applying normal lifting pressure with proper hand tools.	Cover can be removed and reinstalled by one maintenance person with proper hand tools.
	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2 inch or evidence of soil particles entering the structure through the cracks, or qualified maintenance or inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2 inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4 inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking warping, and/or showing signs of failure as determined by qualified maintenance or inspection personnel.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, has eracked/broken rungs, and/or is misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.
Below Ground Cartridge Type	Media clogged	Drawdown of water through the media takes longer than 1 hour, and/or overflow occurs frequently.	Media cartridges replaced.
	Flow short Circuited	Flows do not properly enter filter cartridges.	Filter cartridges replaced.

Check manufacturer's operation and maintenance manual for complete maintenance instructions.

No. 16 API Baffle Oil/Water Separators

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Discharged Water Not Clean	Water discharged from facility has obvious signs of poor water quality.	Treated stormwater discharged from vault should be clear without thick visible sheen.
	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6 inches in depth.	No sediment deposits on vault bottom that would impede flow through the vault and reduce separation efficiency.
	Trash and Debris Accumulation	Trash and debris accumulation in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault, and inlet/outlet piping.
	Oil Accumulation	Oil accumulations that exceed 1 inch, at the surface of the water.	Extract oil from vault by vactoring. Disposal in accordance with state and local regulations.
	Damaged Pipes	Inlet or outlet pipes damaged or broken and in need of repair.	Pipes repaired or replaced.
	Access Hole Cover Damaged/Not Working	One maintenance person cannot remove lid after applying normal lifting pressure with proper hand tools.	Cover can be removed and reinstalled by one maintenance person with proper hand tools.
	Vault Structure Damage Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2 inch or evidence of soil particles entering the structure through the cracks, or qualified maintenance or inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2 inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4 inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by qualified maintenance or inspection personnel.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, has cracked/broken rungs, and/or is misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.

No. 17 Coalescing Plate Oil/Water Separators

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Discharged Water Not Clean	Water discharged from facility has obvious signs of poor water quality.	Treated stormwater discharged from vault should be clear with no thick visible sheen.
	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6 inches in depth and/or visible signs of sediment on plates.	No sediment deposits on vault bottom and plate media, which would impede flow through the vault and reduce separation efficiency.
	Trash and Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault, and inlet/outlet piping.
	Oil Accumulation	Oil accumulation that exceeds 1 inch at the water surface.	Oil is extracted from vault using vactoring methods. Coalescing plates are cleaned by thoroughly rinsing and flushing. Should be no visible oil depth on water.
	Damaged Coalescing Plates	Plate media broken, deformed, cracked and/or showing signs of failure.	A portion of the media pack or the entire plate pack is replaced depending on severity of failure.
	Damaged Pipes	Inlet or outlet pipes damaged or broken and in need of repair.	Pipes repaired and or replaced.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by qualified maintenance or inspection person.	Baffles repaired or replaced to specifications.
	Vault Structure Damage Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2 inch or evidence of soil particles entering the structure through the cracks, or qualified maintenance or inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2 inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4 inch at the joint of the inlet/outlet pipe.
	Access Hole Cover Damaged/Not Working	One maintenance person cannot remove lid after applying normal lifting pressure with proper hand tools.	Cover can be removed and reinstalled by one maintenance person with proper hand tools.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, has eracked/broken rungs, and/or is misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.

No. 18 Catchbasin Inserts

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Sediment Accumulation	When sediment forms a cap over the insert media of the insert and/or unit.	No sediment cap on the insert media and its unit.
	Trash and Debris Accumulation	Trash and debris accumulates on insert unit ereating a blockage/restriction.	Trash and debris removed from insert unit. Runoff freely flows into catch basin.
	Media Insert Not Removing Oil	Effluent water from media insert has a visible sheen.	Effluent water from media insert is free of oils and has no visible sheen.
	Media Insert Water Saturated	Catch basin insert is saturated with water and no longer has the capacity to absorb.	Remove and replace media insert
	Media Insert-Oil Saturated	Media oil saturated due to petroleum spill that drains into catch basin.	Remove and replace media insert.
	Media Insert Use Beyond Normal Product Life	Media has been used beyond the typical average life of media insert product.	Remove and replace media at regular intervals, depending on insert product.

No. 19 Media Filter Drain

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits on grass treatment area of the swale. When finished, swale should be level from side to side and drain freely toward outlet. There should be no areas of standing water once inflow has ceased. Reseed any bare spots as needed in loosened, fertile soil.
	Poor Vegetation Coverage	When grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom.	Determine why grass growth is poor and correct that condition. Replant with plugs of grass from the upper slope: plant in the swale bottom at 8 inch intervals. Or reseed into loosened, fertile soil.
	Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.	Mow vegetation or remove nuisance vegetation so that flow not impeded. Grass should be mowed to a height of 3 to 4 inches. Remove grass clippings.
	Inlet/Outlet	Inlet/outlet areas clogged with sediment and/or debris.	Remove material so that there is no clogging or blockage in the inlet and outlet area.
	Trash and Debris Accumulation	Trash and debris accumulated in the bio-swale.	Remove trash and debris from swale.
	Erosion/Scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. If bare areas are large, generally greater than 12 inches wide, the swale should be regraded and reseeded. For smaller bare areas, overseed when bare spots are evident, or take plugs of grass from the upper slope and plant in the swale bottom at 8 inch intervals.

No. 20 - Compost Amended Vegetated Filter Strip (CAVFS)

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits on grass treatment area of the swale. When finished, swale should be level from side to side and drain freely toward outlet. There should be no areas of standing water once inflow has ceased. Reseed any bare spots as needed in loosened, fertile soil.
	Poor Vegetation Coverage	When grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom.	Determine why grass growth is poor and correct that condition. Replant with plugs of grass from the upper slope: plant in the swale bottom at 8 inch intervals. Or reseed into loosened, fertile soil.
	Vegetation	When the grass becomes excessively tall (greater than 10 inches); when nuisance weeds and other vegetation starts to take over.	Mow vegetation or remove nuisance vegetation so that flow not impeded. Grass should be mowed to a height of 3 to 4 inches. Remove grass clippings.
	Inlet/Outlet	Inlet/outlet areas clogged with sediment and/or debris.	Remove material so that there is no clogging or blockage in the inlet and outlet area.
	Trash and Debris Accumulation	Trash and debris accumulated in the bioswale.	Remove trash and debris from swale.
	Erosion/Scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. If bare areas are large, generally greater than 12 inches wide, the swale should be regraded and reseeded. For smaller bare areas, overseed when bare spots are evident, or take plugs of grass from the upper slope and plant in the swale bottom at 8-inch intervals.

No. 21 - Bioretention Facilities

Component	Defect	Condition When Maintenance is Needed	Maintenance Action and Expected Results
Inlet	Energy dissipaters are damaged	Visible soil, missing rock, or other evidence of damage	Replace or rebuild energy dissipaters to design specifications
	Inlet is blocked	Flow into bioretention bed is impeded	Remove blockage to restore flow
Bioretention bed / plants	Sediment accumulation	Sediment depth exceeds 1 inch	Remove sediment to restore permeability
	Trash or debris	Trash or debris are accumulated on bed	Remove trash and debris

	Excessive drawdown time	Drawdown time > 48 hours	Remove and replace mulch or bioretention soil mix to restore permeability, and/or clean underdrain
	Uneven ponding	Water does not pond evenly on bed	Remove, replace, or reposition mulch to restore even ponding
	Bioretention plants	Bioretention plants are missing, diseased, or dead	Replace plants with healthy bioretention plants selected per the planting plan
	Weeds or invasive plants	Weeds or invasive plants growing in bioretention facility	Remove weeds and invasive plants, replace with bioretention plants or cover affected areas with mulch, as appropriate
	Mulch is inadequate	Mulch is missing	Replace mulch to maintain 2-3 inch depth in mulched areas of bioretention system
	Bed compaction	Bed is compacted due to foot or vehicle traffic or other reason	Loosen compacted bed material, or replace as needed, to restore permeability
Sidewalls, check dams, weirs	Visible damage or erosion	Sidewalls, check dams, or weirs have visible erosion or other structural damage	Repair to bring into conformance with facility design
	Flow over check dams or weirs is blocked	Flow is blocked so that design ponding depth is exceeded	Clear blockage to restore design ponding depth
	Flow around check dams or weirs	Flow is going around check dams or weirs so that design ponding depth is not attained	Repair check dams, weirs, and sidewalls to restore design ponding depth
	Grade board or weir top not level	Uneven flow over check dams or weirs so that design ponding depth is not attained	Repair check dams and weirs to restore design ponding depth
Overflow	Energy dissipaters are damaged	Visible soil, missing rock, or other evidence of damage	Replace or rebuild energy dissipaters to design specifications
	Overflow is blocked	Flow is blocked so that standing pool depth is above design depth	Clear overflow structure to restore design ponding depth
Underdrain system	Underdrain is blocked or damaged	Flow does not pass as designed through underdrain system	Clean or repair underdrain system to restore design flow capacity

No. 22 Permeable Pavement

Pavement type	Defect	Condition When Maintenance is Needed	Maintenance Action and Expected Results
All types	Unstable soil on adjacent area	Runoff from adjacent areas deposits soil, mulch, or sediment on permeable pavement	Remove deposited material from pavement, and stabilize adjacent areas so that further deposition of material on pavement will not occur.
	Adjacent vegetation is covering permeable pavement	Vegetation impedes infiltration in permeable pavement	Trim or remove vegetation so that infiltration is not impeded
	Unwanted vegetation or moss is growing in or on permeable pavement	Unwanted vegetation impedes infiltration in permeable pavement or displaced desired vegetation	Remove unwanted vegetation, repair permeable pavement as needed, replace desired vegetation as needed
	None (routine maintenance)	N/A	Vacuum or sweep according to equipment manufacturer's specifications so that infiltration is not impeded
	Debris or sediment on pavement	Sediment or debris deposits are visible on pavement	Remove sediment or debris and vacuum or sweep according to equipment manufacturer's specifications so that infiltration is not impeded
	Infiltration capacity is reduced	Water ponds on pavement or runs off pavement during rain events	Vacuum or sweep according to equipment manufacturer's specifications so that infiltration is not impeded
	Settlement	Settlement of pavement impedes infiltration	Restore pavement to design grade
Porous asphalt and pervious concrete	Cracks in pavement	Pavement spalls or ravels at crack edges	Patch or cut and replace the affected area with paving material similar to the original pavement. Replace in kind where feasible. Porous asphalt may be replaced with conventional asphalt if it is a small percentage of the total permeable pavement area and does not impact the overall permeable pavement function.
Permeable pavers	Paving block missing or damaged	Paving block missing or damaged	Repair or replace missing or damaged pavers according to manufacturer's specifications
Open-celled paving grid	Paving grid missing or damaged	Three or more adjacent rings in paving grid missing or damaged	Repair or replace missing or damaged paving grid according to manufacturer's specifications
	Loss of aggregate in paving grid	Loss of aggregate in paving grid	Replenish aggregate material in grid to manufacturer's specifications
	Poor / missing grass in vegetated paving grid	Poor / missing grass in vegetated paving grid	Replace growing medium in grid, replant or reseed with grass
Pipe inlet / outlet / underdrain system	Pipe system is blocked or damaged	Flow does not pass as designed through pipe system	Clean or repair pipe system to restore design flow capacity

No. 20 Vortechs Systems

Drainage System Feature	Potential Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed Or Not Needed
General	Sediment Accumulation	Sediment depth is within 12 through 18 inches of dry weather water surface elevation.	Accumulated sediment should be removed.
	Trash and Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault, and inlet/outlet piping.
	Oil Accumulation	Oil accumulation that exceeds 1—inch at the water surface.	Oil is extracted from vault using vactoring methods. Coalescing plates are cleaned by thoroughly rinsing and flushing. Should be no visible oil depth on water.
		See Wet Vaults (No.	12)

Check manufacturer's operation and maintenance manual for complete maintenance instructions.

No. 21 - Conveyance Storm Pipes

Drainage System Feature	Potential Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed Or Not Needed
General	Obstructions, Including Roots	Root enters or deforms pipe, reducing flow.	Use mechanical methods to remove root if possible. Use of chemicals to remove roots shall be done in accordance with applicable regulations. If necessary, remove the vegetation over the line.
	Pipe Dented or Broken	Inlet/outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
	Pipe Rusted or Deteriorated	Any part of the piping that is crushed or deformed more than 20% or any other failure to the piping.	Pipe repaired and/or replaced.
	Sediment & Debris	Sediment depth is greater than 20% of pipe diameter.	Install upstream debris traps (where applicable) then clean pipe and remove material.
	Debris barrier or Trash Rack Missing	A debris barrier or trash rack that had been installed on the end of a drainage pipe is missing	Debris barrier or trash rack is replaced.
	Joint/Seal Problems	The joint between pipe sections is separated and/or the seal at the joint is cracked or broken.	The joint and/or seal is repaired so that joint is not separated and is properly sealed.

No. 22 - Facility Discharge Points

Drainage System Feature	Potential Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed Or Not Needed
Monitoring	Inspection of Discharge Water for Obvious Signs of Poor Water Quality.	Sheen, obvious oil or other contaminants present.	Identify and eliminate pollution source AND report discharge to Snohomish County Surface Water Management Division. Effluent discharge from facility should be clear.
	Receiving Area Saturated	Water in receiving area is causing substrate to become saturated and unstable.	Receiving area sound.

General	Rock Pad Missing or Moved Rock	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil where pad was originally installed.	Rock pad replaced to design standards.
•	Rock Pad- Erosion	Soil erosion in or adjacent to rock pad.	Rock pad replaced to design standards.
	Obstructions, Including Roots	Roots or debris enters pipe or deforms pipe, reducing flow	Use mechanical methods to remove root if possible. Use of chemicals to remove roots shall be done in accordance with applicable regulations. If necessary, remove the vegetation over the line
	Pipe Rusted or Deteriorated	Any part of the pipe that is broken, crushed or deformed more than 20% or any other failure to the piping	Pipe repaired or replaced.

No. 23 - Access Gates

Maintenance Component	Defect	Condition When Maintenance is Needed	Maintenance Action and Expected Results
General	Damaged or missing components	Gate and/or locking mechanism condition is such that access is impeded.	Gate and locking mechanism are fully functional for access purposes.
	Damaged or missing components	Broken or missing hinges such that gate cannot be easily opened and closed by a maintenance person.	Hinges intact and lubed. Gate is working freely.
	Damaged or missing components	Gate is out of plumb more than 6 inches and more than 1 foot out of design alignment.	Gate is aligned and vertical (plumb).
	Damaged or missing components	Missing stretcher bands, and ties.	Stretcher bar, bands, and ties in place.

No. 24 Access Roads

Maintenance Component	Defect	Condition When Maintenance is Needed	Maintenance Action and Expected Results
General	Road Surface	Condition of road surface may lead to erosion of the facility or limit access.	Road repaired.
	Erosion of Ground Surface	Noticeable rills are seen in landscaped areas.	Causes of erosion are identified and steps taken to slow down/spread out the water. Eroded areas are filled, contoured, and seeded. If needed, regrade affected areas.
	Vegetation	Function of road is impaired by vegetation	Vegetation is removed or managed to restore proper function of facility. Use of herbicides shall be in accordance with applicable regulations.
	Tree Growth	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements). If trees are	Trees do not hinder maintenance activities.

not interfering with access of maintenance, do not remove	
Trees or shrubs that have over road.	fallen Fallen trees or shrubs removed from road.

Chapter 5 On-Site Stormwater Management and LID BMPs

5.1 Purpose

This chapter presents the methods for analysis and design of on-site stormwater management best management practices (BMPs), which are defined in Snohomish County Code (SCC) as "those best management practices designed to meet Minimum Requirement 5 specified in 30.63A.525 SCC and described in Volume I of the Snohomish County Drainage Manual."

This chapter also presents other BMPs that, while not required for consideration in compliance with 30.63A.525 SCC, fall into the categories of low impact development BMPs or low impact development as those terms are defined in Snohomish County Code.

5.2 Application

Minimum Requirement 5, as set forth in SCC 30.63A.525, requires the use of various on-site stormwater management BMPs provided they are not infeasible according to criteria set forth in this manual. Volume I, Chapter 2 sets forth the selection process for these BMPs. Volume III, Chapter 3 contains specific information for the following on-site stormwater management BMPs:

- BMP T5.10A Downspout Full Infiltration Systems
- BMP T5.10B Downspout Dispersion Systems
- BMP T5.10C Perforated Stub-out Connections

The remaining on-site stormwater management BMPs required for consideration under Minimum Requirement 5 and described in this chapter are:

- BMP T5.11 Concentrated Flow Dispersion
- BMP T5.12 Sheet Flow Dispersion.
- BMP T5.13 Post-Construction Soil Quality and Depth
- BMP T5.14A Rain Gardens
- BMP T5.14B Bioretention
- BMP T5.15 Permeable Pavement
- BMP T5.30 Full Dispersion

This chapter also contains information about the following BMPs that are not required for consideration under Minimum Requirement 5, but which may be used to help meet the flow control requirements of Minimum Requirement 7, or otherwise ensure implementation of stormwater site planning principles set forth in Volume I, Chapter 3:

- BMP T5.16 Tree Retention and Tree Planting
- BMP T5.17 Vegetated Roofs
- BMP T5.18 Reverse Slope Sidewalks
- BMP T5.19 Minimal Excavation Foundations

- BMP T5.20 Rainwater Harvesting
- BMP T5.40 Preserving Natural Vegetation
- BMP T5.41 Better Site Design

The Underground Injection Control (UIC) regulations of Chapter 173-218 WAC apply to stormwater infiltration systems, although those regulations contain exemptions for various kinds of stormwater infiltration systems. These regulations are implemented by the Washington State Department of Ecology, and Snohomish County recommends that the applicant contact that department for project-specific determinations about UIC regulation applicability. Snohomish County does not implement or enforce the state UIC regulations.

5.3 On-Site Stormwater Management BMPs

Section 5.3 sets forth information for the BMPs, other than those described in Volume III Chapter 3, that must be considered for compliance with Minimum Requirement 5.

BMP T5.11 Concentrated Flow Dispersion

Applications and Limitations

Concentrated flow dispersion can be used in any situation where flow will be concentrated but can be dispersed through native vegetation or developed vegetated areas with soil amended to meet the requirements of BMP T5.13 - Post-Construction Soil Quality and Depth. A typical example, shown in Figure 5.3, is a steep driveway in which runoff must be concentrated in order to divert it to dispersion trenches.

Infeasibility criteria for Concentrated Flow Dispersion

Concentrated flow dispersion systems are considered infeasible in the following circumstances:

- if a vegetated flowpath of 25 feet or more cannot be provided;
- if the use of a dispersion system might cause erosion or flooding problems onsite or on adjacent properties;
- if the discharge point can only be located on or above a slope greater than 20% or above erosion hazard areas, unless these locations are determined to not pose erosion or slope stability hazards by the project engineer; or
- if the discharge point can only be located upslope of primary and reserve septic system drainfield areas, unless site topography clearly prohibits flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that this is unnecessary.

Design criteria for Concentrated Flow Dispersion

- Setback and separation requirements are set forth in SCC 30.63A.710. In addition, a minimum 25-foot vegetated flow path is required between the discharge point of the dispersion trench and any property line, structure, steep slope, stream, lake, wetland, lake, or other impervious surface. If the flow path is 25 50 feet long, flows must be distributed using a dispersion trench (see Volume III, Chapter 3, BMP T5.10B) as a prerequisite to use of the lateral flow element.
- A maximum of 700 square feet of impervious area may drain to each dispersion trench.
- Provide a pad of crushed rock at least 2 feet wide, 3 feet long, and 6 inches deep at each discharge point.

Hydrologic modeling credit for concentrated flow dispersion Runoff model representation

Where BMP T5.11 is used to disperse runoff into an undisturbed native landscape area or an area that meets BMP T5.13 (Post-Construction Soil Quality and Depth), the impervious area should be modeled as a lateral flow impervious basin connected to a lawn/landscape lateral flow basin which represents the area used for dispersion. and Alternatively, where multiple instances of concentrated flow dispersion will occur the following methods may be used.

• If the vegetated flow path is at least 50 feet, the impervious area may be modeled as landscaped area.

• Where the vegetated flowpath is 25 – 50 feet, using a dispersion trench (see BMP T5.10B) allows modeling the impervious area as 50% impervious/50% landscape. This is done in the WWHM 3 on the Mitigated Scenario screen by entering the dispersed impervious area into one of the entry options for dispersal of impervious area runoff. For procedures in WWHM 2012, see Volume III, Appendix III C.

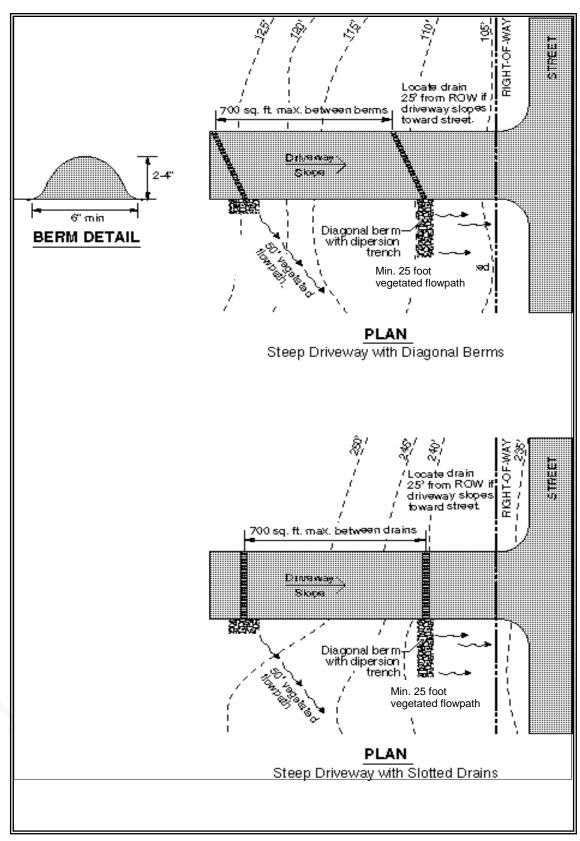


Figure 5.3 – Typical Concentrated Flow Dispersion for Steep Driveways

BMP T5.12 Sheet Flow Dispersion

Applications and Limitations

Sheet flow dispersion can be used in areas with a slope of 15% or less where flow can be dispersed through native vegetation or developed vegetated areas with soil amended to meet the requirements of BMP T5.13 - Post-Construction Soil Quality and Depth. For areas with slopes greater than 15%, dispersion if feasible must be achieved by using BMP T5.11, Concentrated Flow Dispersion.

Infeasibility criteria for Sheet Flow Dispersion

Sheet flow dispersion systems are considered infeasible in the following circumstances:

- If a minimum 10-foot flow path per every 20 feet of contributing surface flow path cannot be provided;
- if the use of a dispersion system might cause erosion or flooding problems onsite or on adjacent properties;
- if the BMP can only be located on or above a slope greater than 20% or above erosion hazard areas, unless these locations are determined to not pose erosion or slope stability hazards by the project engineer; or
- if the discharge area cannot be located more than 10 feet downgradient of primary and reserve septic system drainfield areas, unless site topography clearly prohibits flows from intersecting the drainfield or where site conditions (soil permeability, distance between systems, etc.) indicate that this is unnecessary.

Design criteria for Sheet Flow Dispersion

Figure 5.4 shows sheet flow dispersion using a dispersion trench, and also shows sheet flow from pavement discharged through a "transition zone." The dispersion trench option, shown in the upper drawing in the figure, is identical to that used in BMP T5.11 - Concentrated Flow Dispersion. The transition zone option, shown in the lower drawing in the figure, involves direct discharge of sheet flow from the contributing surface impervious through a two-foot wide strip constructed of one of several materials.

Sheet flow dispersion using a dispersion trench

The design criteria and hydrologic modeling creditrunoff model representation are the same as those set forth for a dispersion trench in BMP T5.11 - Concentrated Flow Dispersion.

Sheet flow dispersion using a transition zone

- Sheet flow from the contributing surface shall be discharged into a two-foot-wide transition zone between the edge of the contributing surface and the downslope vegetation. The transition zone shall consist of an extension of pavement subgrade material, modular pavement, or drain rock.
- The transition zone material must be placed on top of soil amended according to the criteria of BMP T5.13.

• For up to 20 feet of contributing surface flow path, a 10-foot sheet flow dispersion flow path shall be provided between the edge of the transition zone and any property line, structure, steep slope, stream, lake, wetland, lake, or other impervious surface. An additional 10 feet of flow dispersion path shall be added for each additional 20 feet of contributing surface flow path, or any fraction thereof.

Hydrologic modeling credit for sheet flow dispersion Runoff model representation

Where BMP T5.12 is used to disperse runoff into an undisturbed native landscape area or an area that meets BMP T5.13, the impervious area should be modeled as a lateral flow impervious basin connected to a lawn/landscape lateral flow basin which represents the area used for dispersion and the vegetated flow path is 50 feet or more, the impervious area may be modeled as landscaped area. Where the vegetated flowpath is 25 to 50 feet, use of a dispersion trench (see BMP T5.10B) allows modeling the impervious area as 50% impervious/50% landscape. This is done in the WWHM3 on the Mitigation Scenario screen by entering the dispersed impervious area into one of the entry options for dispersal of impervious area runoff. For procedures in WWHM 2012, see Appendix III-C in Volume III.

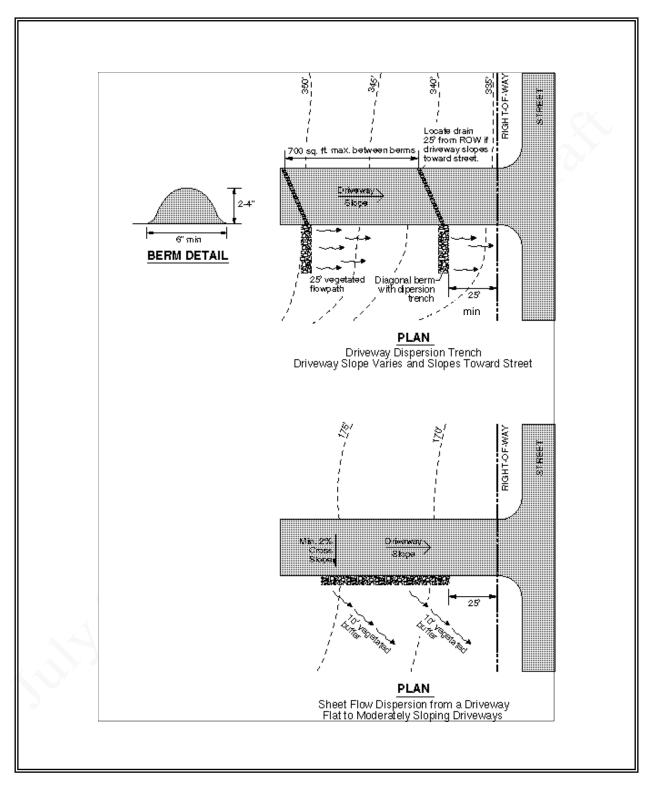


Figure 5.4 – Sheet Flow Dispersion

BMP T5.13 Post-Construction Soil Quality and Depth

Purpose and definition

Naturally occurring (undisturbed) soil and vegetation provide important stormwater functions including: water infiltration; nutrient, sediment, and pollutant adsorption; sediment and pollutant biofiltration; water interflow storage and transmission; and pollutant decomposition. These functions are largely lost when development strips away native soil and vegetation and replaces it with minimal topsoil and sod. Not only are these important stormwater functions lost, but such landscapes themselves become pollution- generating pervious surfaces due to increased use of pesticides, fertilizers and other landscaping and household/industrial chemicals, the concentration of pet wastes, and pollutants that accompany roadside litter.

Establishing soil quality and depth regains greater stormwater functions in the post development landscape, provides increased treatment of pollutants and sediments that result from development and habitation, and minimizes the need for some landscaping chemicals, thus reducing pollution through prevention.

Applications and limitations

Establishing a minimum soil quality and depth is not the same as preservation of naturally occurring soil and vegetation. However, establishing a minimum soil quality and depth will provide improved on-site management of stormwater flow and water quality.

Soil organic matter can be attained through numerous materials such as compost, composted woody material, biosolids, and forest product residuals. It is important that the materials used to meet the soil quality and depth BMP be appropriate and beneficial to the plant cover to be established. Likewise, it is important that imported topsoils improve soil conditions and do not have an excessive percent of clay fines.

More than one method may be used on different portions of the same site. Soil that already meets the depth and organic matter quality standards, and is not compacted, does not need to be amended.

Infeasibility criteria for Post-construction Soil Quality and Depth

This BMP is considered infeasible on till soils with a slope greater than 33%.

Design criteria

- <u>Soil retention</u>. The duff layer and native topsoil should be retained in an undisturbed state to the maximum extent practicable. In any areas requiring grading remove and stockpile the duff layer and topsoil on site in a designated, controlled area, not adjacent to public resources and critical areas, to be reapplied to other portions of the site where feasible.
- <u>Soil quality</u>. The resulting soil should be conducive to the type of vegetation to be established. All areas subject to clearing and grading that have not been covered by impervious surface, incorporated into a drainage facility or engineered as structural fill or slope shall, at project completion, demonstrate the following:
 - A topsoil layer with a minimum organic matter content of ten percent dry weight in planting beds, and 5% organic matter content (based on a loss-on-ignition test) in turf areas, and a pH from 6.0 to 8.0 or matching the pH of the original undisturbed soil. The

topsoil layer shall have a minimum depth of eight inches except where tree roots limit the depth of incorporation of amendments needed to meet the criteria. Subsoils below the topsoil layer should be scarified at least 4 inches with some incorporation of the upper material to avoid stratified layers, where feasible.

- o Planting beds must be mulched with 2 inches of organic material.
- o Quality of compost and other materials used to meet the organic content requirements:
 - 1. The organic content for "pre-approved" amendment rates can be met only using compost meeting the compost specification for Bioretention (BMP T7.30), with the exception that the compost may have up to 35% biosolids or manure.
 - 2. Compost used in bioretention areas should be stable, mature and derived from yard debris, wood waste, or other organic materials that meet the intent of the organic soil amendment specification. Biosolids and manure composts can be higher in bioavailable phosphorus than compost derived from yard or plant waste and therefore are not allowed in bioretention areas due to the possibility of exporting bio-available phosphorus in effluent.
 - 3. The compost must also have an organic matter content of 35% to 65%, and a carbon to nitrogen ratio below 25:1.
 - 4. The carbon to nitrogen ratio may be as high as 35:1 for plantings composed entirely of plants native to the Puget Sound Lowlands region.
- Calculated amendment rates may be met through use of composted material meeting the requirements above; or other organic materials amended to meet the carbon to nitrogen ratio requirements, and not exceeding the contaminant limits identified in Table 220-B, Testing Parameters, in WAC 173-350-220.
- <u>Implementation Options</u>: The soil quality design guidelines listed above can be met by using one of the methods listed below.
 - Leave undisturbed native vegetation and soil, and protect from compaction during construction.
 - o Amend disturbed soil according to the following procedures:
 - 1. Scarify subsoil to a depth of one foot
 - 2. In planting beds, place three inches of compost and till in to an eight-inch depth.
 - 3. In turf areas, place two inches of compost and till in to an eight-inch depth.
 - 4. Apply two to four inches of arborist wood chip, coarse bark mulch, or compost mulch to planting beds after final planting.
 - Amend on a site-customized manner so that it meets the soil quality criteria set forth above, as determined by a licensed engineer, geologist, landscape architect, or other person as approved by Snohomish County.
 - Stockpile existing topsoil during grading, and replace it prior to planting. Stockpiled topsoil must be amended if needed to meet the organic matter and depth requirements by following the procedures in the previous bullet.

• Import topsoil mix of sufficient organic content and depth to meet the organic matter and depth requirements.

Maintenance Construction

- Soil quality and depth should be established toward the end of construction and, once
 established, should be protected from compaction, such as from large machinery use, and
 from erosion.
- Soil should be planted and mulched after installation.
- Plant debris or its equivalent should be left on the soil surface to replenish organic matter.

Flow Reduction CreditsRunoff model representation

All areas meeting the soil quality and depth design criteria may be entered into approved runoff hydrologic models as pasture rather than lawn/landscaping. This includes impervious surfaces modeled as pervious for the following BMPs: Areas meeting the design requirements above can be modeled as "Pasture." Flow reduction credits can be taken in runoff modeling when BMP T5.13 is used as part of a dispersion design under the conditions described in:

- BMP T5.10B Downspout Dispersion Systems
- BMP T5.11 Concentrated Flow Dispersion
- BMP T5.12 Sheet Flow Dispersion
- BMP T5.18 Reverse Slope Sidewalks
- BMP T5.30 Full Dispersion (for public road projects)
- Non-pollution generating impervious surface dispersion BMPs in Volume III, Chapter 3 of this manual.

BMP T5.14A Rain Gardens

Purpose and definition

A rain garden is a vegetated on-site stormwater management BMP consisting of a shallow landscaped depression with specially-amended soils. Rain gardens can be used to infiltrate runoff from roofs and other hard surfaces in project that are required only to meet Minimum Requirements 1 – 5. Rain gardens are similar in structure to bioretention systems, but have less rigorous design requirements and are sized with a method equivalent to that used for BMP T5.10A – Downspout Full Infiltration Systems. Figure 5.5 depicts a typical longitudinal cross-section of a rain garden.

Applications and limitations

Establishing a minimum soil quality and depth is not the same as preservation of naturally occurring soil and vegetation. However, establishing a minimum soil quality and depth will provide improved on-site management of stormwater flow and water quality.

Soil organic matter can be attained through numerous materials such as compost, composted woody material, biosolids, and forest product residuals. It is important that the materials used to meet the soil quality and depth BMP be appropriate and beneficial to the plant cover to be established. Likewise, it is important that imported topsoils improve soil conditions and do not have an excessive percent of clay fines.

Infeasibility criteria

Infeasibility criteria for rain gardens are the same as those for BMP T7.30 – Bioretention.

Design criteria

Sizing criteria

The ratio of the plan view area of ponded water below the overflow to the area contributing runoff shall be determined by Table 5.4, based on soil type. These ratios were derived from the design criteria for BMP T5.10A – Downspout Full Infiltration Systems. NOTE: if the rain garden is used as a BMP to satisfy Minimum Requirement 5 for runoff from hard surfaces other than roofs, areas of permeable pavement need not be included in the contributing area.

Underdrains

Underdrains are allowed but not required in rain gardens. The invert of an underdrain shall be a minimum of 6 inches above the bottom of the aggregate bedding for the underdrain. Note that a determination of infeasibility for a rain garden cannot be based upon the inclusion of an underdrain.

Rain garden soil

Amend the native soil with compost that meets the requirements of that used for bioretention soil mix in accordance with the requirements set forth in BP T7.30 – Bioretention. Compost meeting the requirements of BMP T5.13 is not acceptable, since it can contain biosolids and manure, which are not allowed in rain gardens.

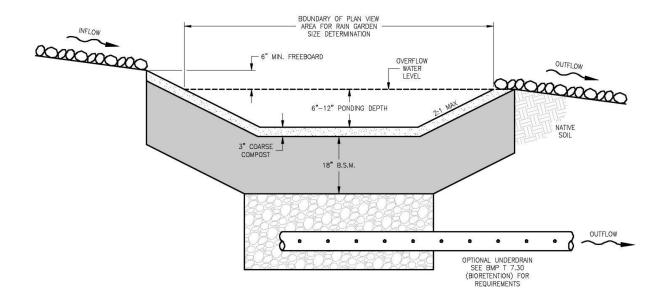


Figure 5.5 – Typical Rain Garden Longitudinal Section

Setback and separation distances

Setback and separation requirements are set forth in SCC 30.63A.710. In addition, rain gardens shall be separated a minimum of 5 feet from building foundations, and set back a minimum of 5 feet from property lines.

Construction

Requirements for erosion and sedimentation control during construction, excavation, soil placement, and installation shall be in accordance with those for BMP T7.30 – Bioretention set forth in this volume.

Maintenance

Use applicable sections of bioretention system maintenance methods set forth in Chapter 4.6 of this volume. See the requirements set forth in Chapter 4.6 of this volume and in applicable bioretention system maintenance methods and standards in Volume VI Stormwater Facility Maintenance.

Table 5.4 – Rain Garden Plan View Area Based on Soil Type

Soil type	Ratio of plan view below overflow to contributing area (ft²)
Loam	0.38
Sandy loam	0.25
Loamy sand	0.15
"Fine sand" - less than 50% of <u>sand</u> <u>fraction</u> remaining on #40 sieve	0.15
"Medium sand" - more than 50% of sand fraction remaining on #40 sieve	0.06
"Coarse sand" - more than 50% of <u>sand</u> <u>fraction</u> remaining on #4 sieve	0.05
Fill <u>*</u> -(1)	0.12

Note: *-(1)—Rain gardens shall <u>not</u> be placed in fill material unless the fill is placed and compacted under the direct supervision of a geotechnical engineer or civil engineer with geotechnical expertise, <u>and</u> if the measured infiltration rate is at least 8 inches per hour.

BMP T5.14B Bioretention for On-site Stormwater Management

Purpose and definition

Bioretention systems are vegetated stormwater management systems consisting of an excavated area partially filled with a bioretention soil mix and replanted using plants from a specific list. Bioretention systems can be designed and constructed as on-site stormwater management BMPs used to comply with Minimum Requirement 5, or can be designed and constructed using different criteria to serve as stormwater treatment systems for compliance with Minimum Requirement 6. In addition, bioretention systems can also provide infiltration that serves to partially or fully meet Minimum Requirement 7.

Infeasibility criteria

See infeasibility criteria for BMP T7.30 – Bioretention in Chapter 7 of this volume.

Design criteria

See design criteria for BMP T7.30 – Bioretention in Chapter 7 of this volume.

Setback and separation distances

Setback and separation requirements are set forth in SCC 30.63A.710. In addition, bioretention systems for on-site stormwater management shall be separated a minimum of 5 feet from building foundations, and set back a minimum of 5 feet from property lines.

Maintenance

See maintenance criteria for bioretention in Chapter 4.6 of this volume. See the requirements set forth in Chapter 4.6 of this volume and in applicable bioretention system maintenance methods and standards in Volume VI Stormwater Facility Maintenance.

Hydrologic modeling credits Runoff model representation

See <u>hydrologic modeling creditsrunoff model representation</u> for BMP T7.30 – Bioretention in Chapter 7 of this volume.

BMP T5.15 Permeable Pavement

Purpose and definition

There are a number of variations of permeable pavement. Variables include the basic paved surface material (typically asphalt or concrete), whether the pavement is a contiguous surface of permeable material, or an array of blocks or pieces of impermeable material installed so that water can infiltrate through the spaces between the pavers, and whether vegetation such as grass is intentionally included in the system. The Snohomish County EDDS contains detailed information about the types of permeable pavement allowed by Snohomish County.

This chapter contains information about the drainage design and hydrologic modeling aspects of permeable pavement. <u>Information about materials, structural design, and construction of permeable pavement is set forth in Snohomish County EDDS Chapter 11, except for subgrade load-bearing requirements which are set forth in Snohomish County EDDS Chapter 4.</u>

Applications and stormwater-related limitations

Permeable paving surfaces are an important integrated management practice within the LID approach and can be designed to accommodate pedestrian, bicycle and auto traffic while allowing infiltration, treatment and storage of stormwater.

Permeable pavements are appropriate in many applications where traditionally impermeable pavements have been used. Typical applications for permeable paving include parking lots, sidewalks, pedestrian and bike trails, driveways, residential access roads, and emergency and facility maintenance roads.

From a stormwater perspective, the limitations of permeable pavement are:

- No run-on from pervious surfaces is preferred. If runoff comes from minor or incidental pervious areas, those areas must be fully stabilized.
- Unless the pavement, base course, and subgrade have been designed to accept runoff from adjacent impervious surfaces, slope impervious runoff away from the permeable pavement to the maximum extent practicable. Sheet flow from up-gradient impervious areas is not recommended, but permissible if the permeable pavement area is greater than the impervious pavement area.
- Soils must not be tracked onto the wear layer or the base course during construction

Infeasibility criteria for permeable pavement

Permeable pavement is considered infeasible if any of the following conditions exist.

These criteria also apply to impervious pavements that redistribute stormwater into the base material below the pavement.

Citation of any of the following infeasibility criteria must be based on an evaluation of site-specific conditions and a written recommendation from an appropriate licensed professional (e.g., engineer, geologist, hydrogeologist):

• Where professional geotechnical evaluation recommends infiltration not be used due to reasonable concerns about erosion, slope failure, or down gradient flooding.

- Within an area whose ground water drains into an erosion hazard, or landslide hazard area.
- Where infiltrating and ponded water below new permeable pavement area would compromise adjacent impervious pavements.
- Where infiltrating water below a new permeable pavement area would threaten existing below grade basements.
- Where infiltrating water would threaten shoreline structures such as bulkheads.
- Down slope of steep, erosion prone areas that are likely to deliver sediment.
- Where fill soils are used that can become unstable when saturated.
- Excessively steep slopes where water within the aggregate base layer or at the sub-grade surface cannot be controlled by detention structures and may cause erosion and structural failure, or where surface runoff velocities may preclude adequate infiltration at the pavement surface.
- Where permeable pavements cannot provide sufficient strength to support heavy loads at industrial facilities such as ports.
- Where installation of permeable pavement would threaten the safety or reliability of preexisting underground utilities, pre-existing underground storage tanks, or pre-existing road sub-grades.

The following criteria can be cited as reasons for a finding of infeasibility without further justification (though some require professional services to make the observation):

- Within an area designated as an erosion hazard, or landslide hazard.
- Within 50 feet from the top of slopes that are greater than 20%.
- For properties with known soil or ground water contamination (typically federal Superfund sites or state cleanup sites under the Model Toxics Control Act (MTCA)):
 - o Within 100 feet of an area known to have deep soil contamination;
 - Where ground water modeling indicates infiltration will likely increase or change the direction of the migration of pollutants in the ground water;
 - Wherever surface soils have been found to be contaminated unless those soils are removed within 10 horizontal feet from the infiltration area:
 - Any area where these facilities are prohibited by an approved cleanup plan under the state Model Toxics Control Act or Federal Superfund Law, or an environmental covenant under Chapter 64.70 RCW.
- Within 100 feet of a closed or active landfill.
- Within 100 feet of a drinking water well, or a spring used for drinking water supply, if the pavement is a pollution-generating surface.
- Within 10 feet of a small on-site sewage disposal drainfield, including reserve areas, and grey water reuse systems. For separations from a "large on-site sewage disposal system", see Chapter 246-272B WAC.

- Within 10 feet of any underground storage tank and connecting underground pipes, regardless of tank size. As used in these criteria, an underground storage tank means any tank used to store petroleum products, chemicals, or liquid hazardous wastes of which 10% or more of the storage volume (including volume in the connecting piping system) is beneath the ground surface.
- At multi-level parking garages, and over culverts and bridges.
- Where the site design cannot avoid putting pavement in areas likely to have long-term excessive sediment deposition after construction (e.g., construction and landscaping material yards).
- Where the site cannot reasonably be designed to have a porous asphalt surface at less than 5 percent slope, or a pervious concrete surface at less than 10 percent slope, or a permeable interlocking concrete pavement surface (where appropriate) at less than 12 percent slope.
 Grid systems upper slope limit can range from 6 to 12 percent; check with manufacturer and local supplier.
- Where the native soils below a pollution-generating permeable pavement (e.g., road or parking lot) do not meet the soil suitability criteria for providing treatment. See SSC-6 in Section 3.3.7 of Volume III. Snohomish County may require a six-inch layer of media meeting the soil suitability criteria or the sand filter specification as a condition of construction.
- Where seasonal high ground water or an underlying impermeable/low permeable layer would create saturated conditions within one foot of the bottom of the lowest gravel base course.
- Where underlying soils are unsuitable for supporting traffic loads when saturated as determined by subgrade requirements set forth in Snohomish County EDDS Chapter 4.
- Where appropriate field testing indicates soils have a measured (a.k.a., initial) native soil saturated hydraulic conductivity less than 0.3 inches per hour. (Note: In these instances, unless other infeasibility restrictions apply, roads and parking lots may be built with an underdrain, preferably elevated within the base course, if flow control benefits are desired.)
- Roads that receive more than very low traffic volumes, and areas having more than very low truck traffic. Roads with a projected average daily traffic volume of 400 vehicles or less are very low volume roads (AASHTO, 2001)(U.S. Dept. of Transportation, 2013). Areas with very low truck traffic volumes are roads and other areas not subject to through truck traffic but may receive up to weekly use by utility trucks (e.g., garbage, recycling), daily school bus use, and multiple daily use by pick-up trucks, mail/parcel delivery trucks, and maintenance vehicles. Note: This infeasibility criterion does not extend to sidewalks and other non-traffic bearing surfaces.
- Where replacing existing impervious surfaces unless the existing surface is a non-pollution generating surface over an outwash soil with a saturated hydraulic conductivity of four inches per hour or greater.
- At "high use sites" as described in Volume I, Chapter 4 of this manual.
- In areas with "industrial activity" as identified in 40 CFR 122.26(b)(14).

- Where the risk of concentrated pollutant spills is more likely such as gas stations, truck stops, and industrial chemical storage sites.
- Where routine, heavy applications of sand occur in frequent snow zones to maintain traction during weeks of snow and ice accumulation. Most lowland western Washington areas do not fit this criterion.

Stormwater design criteria

Stormwater infiltration

See Volume III, Chapter 3.3.10 of this manual for information regarding required field testing, assignment of infiltration rate correction factors, project submission requirements, and modeling.

Underdrains

Permeable pavement cannot be used to satisfy Minimum Requirement #5 if it is designed with an underdrain at or near the bottom of the aggregate base. However, permeable pavement designed with an underdrain that is elevated within the aggregate base course can be used to satisfy Minimum Requirement #5. Underdrains elevated within the aggregate base course may protect the pavement wearing course from saturation.

Hydrologic modeling creditsRunoff model representation

Model permeable pavement that has storage in a base course below the wearing surface using the permeable pavement element in the model. Areas of permeable pavement with similar pavement type / design and similar infiltration characteristics can be summed and represented in the model as a single area of permeable pavement with the following characteristics:

- drainage area = combined drainage areas of the individual paved areas;
- ponded area = combined ponded areas of the individual paved areas;
- design infiltration rate = weighted average design infiltration rate, weighted by size of paved area.

Model permeable pavement with no storage in a base course below the wearing surface as lawn/landscape.

See Appendix III C for runoff modeling guidance under WWHM3 and under WWHM 2012. Note that if the project is using permeable pavement to only meet BMP list approach within Minimum Requirement #5, there is no need to model the permeable pavement in a continuous runoff model.

The following guidance information below is to showshall be used to compliance with the LID Performance Standard in Minimum Requirement #5, or the standards in Minimum Requirements #6, #7, and/or #8.

Continuous runoff modeling software include specific modeling elements for use in modeling the permeable pavement. Within these elements, the model user specifies pavement thickness and porosity, aggregate base material thickness and porosity, maximum allowed ponding depth, and the infiltration rate into the native soil.

• For grades less than 2%, no adjustment to the below ground volumes are necessary.

- For grades greater than 2% without internal dams within the base materials, the below ground storage volume must be adjusted as follows:
 - Permeable pavement surfaces that are below the surrounding grade and that are on a slope can be modeled as permeable pavement with an infiltration rate and a nominal depth.
 - o The dimensions of the permeable pavement are: the length (parallel to and beneath the road) of the base materials that are below grade; the width of the below grade base materials; and an Effective Total Depth of 1 inch. If the continuous runoff model requires the permeable pavement to have an overflow riser to model overflows that occur should the available storage get exceeded, enter 0.04 ft (1/2 inch) for the "Riser Height" and a large Riser Diameter (say 1000 inches) to ensure that there is no head build up.
 - O If a drainage pipe is embedded and elevated in the below grade base materials, the pipe should only have perforations on the lower half (below the spring line) or near the invert. Pipe volume and trench volume above the pipe invert cannot be assumed as available storage space. If a drainage pipe is placed at the bottom of the base material, the pavement is modeled as an impervious surface without any gravel trench.
 - For roads on a slope with internal dams within the base materials that are below grade, the below ground storage volume must be adjusted as follows:
 - <u>Separately.</u> Each stretch of permeable pavement (cell) that is separated by barriers can be modeled separately. For each cell, determine the average depth of water within the cell at which the barrier at the lower end will be overtopped.
 - Specify the dimensions of each cell of the below-grade base materials using the permeable pavement dimension fields for: the "Pavement Length" (length of the cell parallel to the road); the "Pavement Bottom Width" (width of the bottom of the base material); and the Effective Total Depth. In WWHM2012, the field entilted "Effective Volume Factor" is used by the program to calculate the effective storage volume within the below-grade base materials for roads on a slope. The Effective Volume Factor is the ratio of the average maximum water depth behind a check dam (typically at the middle of the pavement length) to the below-grade base materials depth.
 - <u>Sech cell should have its own tributary drainage area within the permeable pavement element that includes the road above it, any project site areas whose runoff drains onto and through the road (lateral flow soil or impervious basin), and any off-site areas. Represent each drainage area with a permeable pavement icon and a lateral flow basin icon (if runon occurs).</u>

In the runoff modeling, similar designs throughout a development can be summed and represented as one large facility. For instance, walkways can be summed into one facility. Driveways with similar designs (and enforced through deed restrictions) can be summed into one facility. In these instances, a weighted average of the design infiltration rates (where within a factor of two) for each location may be used. The averages are weighted by the size of their drainage area. The design infiltration rate for each site is the measured Ksat multiplied by the appropriate correction factors.

Within WWHM2012, on the Permeable Pavement screen under "Infiltration", there is a field that asks the following "Use Wetted Surface Area?" By default, it is set to "NO". It should stay "NO" if the below-grade base material trench has sidewalls steeper than 2 horizontal to 1 vertical.

Maintenance

Permeable pavement maintenance requirements are set forth in Chapter 4.6 of this volume. See the requirements and standards set forth in Chapter 4.6 of this volume, and in Volume VI Stormwater Facility Maintenance.

BMP T5.30 Full Dispersion

Purpose and definition

Full dispersion is an on-site stormwater management BMP that can be used to meet Minimum Requirement 5. It involves dispersing the runoff, according to the requirements of this section, from impervious surfaces and cleared areas of development sites that protect at least 65% of the site (or a threshold discharge area on the site) in a forest or native condition. Full dispersion can be used on residential developments that may include roadway construction, and for public road projects that meet the requirements of this section and that are not constructed as part of a residential, commercial, or industrial development project. The roadway design requirements differ for these two cases.

Applications and limitation for residential projects

- Rural single family residential developments should use these dispersion BMPs wherever possible to minimize effective impervious surface to less than 10% of the development site.
- Other types of development that retain 65% of the site (or a threshold discharge area on the site) in a forested or native condition may also use these BMPs to avoid triggering the flow control facility requirement.
- The preserved area may be a previously cleared area that has been replanted in accordance with native vegetation landscape specifications described within this BMP.
- The preserved area should be situated to minimize the clearing of existing forest cover, to maximize the preservation of wetlands (though the wetland area and any streams and lakes do not count toward the 65% forest or native condition area), and to buffer stream corridors.
- The preserved area should be placed in a separate tract or protected through recorded easements for individual lots.
- The preserved area should be shown on all property maps and should be clearly marked during clearing and construction on the site.
- All trees within the preserved area at the time of permit application shall be retained, aside
 from approved timber harvest activities regulated under WAC Title 222, except for Class IV
 General Forest Practices that are conversions from timberland to other uses, and the removal
 of dangerous or diseased trees.
- The preserved area may be used for passive recreation and related facilities, including pedestrian and bicycle trails, nature viewing areas, fishing and camping areas, and other similar activities that do not require permanent structures, provided that cleared areas and areas of compacted soil associated with these areas and facilities do not exceed eight percent of the preserved area.
- The preserved area may contain utilities and utility easements, but not septic systems. Utilities are defined as potable and wastewater underground piping, underground wiring, and power and telephone poles.

Minimum design requirements for residential projects

Developments that preserve 65% of a site (or a threshold discharge area of a site) in a forested or native condition, can disperse runoff from the developed portion of the site into the native vegetation area as long as the developed areas draining to the native vegetation do not have impervious areas that exceed 10% of the entire site.

Where a development has less than 65% of a site available to maintain or create into a forested or native condition, that area may still be used for full dispersion of a portion of the developed area. The ratio of the native vegetation area to the impervious area, which is dispersed into the native vegetation, must not be less than 65 to 10. The lawn and landscaping areas associated with the impervious areas may also be dispersed into the native vegetation area. The lawn and landscaped area must comply with BMP T5.13. All design requirements listed also must be met.

The portion of the developed area which is not managed through full dispersion can be considered a separate project site. It must be evaluated against the thresholds in Figures 2.2 and 2.3 of Volume I, whichever is appropriate, to determine the applicable minimum requirements.

Additional impervious areas above the 10% threshold are allowed, but should not drain to the native vegetation area, and are subject to the thresholds, treatment and flow control requirements of this manual.

Within the context of this dispersion option, the impervious surfaces over the 10% maximum threshold can be routed into an appropriately sized dry well or into an infiltration basin that meets the flow control standard and does not overflow into the forested or native vegetation area.

Runoff must be dispersed into the native area in accordance with one or more of the dispersion devices, and in accordance with the design criteria and limits for those devices, cited in this BMP. A native vegetation flow path of at least 100 feet in length (25 feet for sheet flow from a non-native pervious surface) must be available along the flowpath that runoff would follow upon discharge from a dispersion device cited in this BMP. The native vegetated flowpath must meet all of the following criteria:

- The flow path must be over native vegetated surface
- The flow path must be on-site or in an off-site tract or easement area reserved for such dispersion
- The slope of the flowpath must be no steeper than 15% for any 20-foot reach of the flowpath. Slopes up to 33% are allowed where level spreaders are located upstream of the dispersion area and at sites where vegetation can be established.
- The flowpath must be located between the dispersion device and any downstream drainage feature such as a pipe, ditch, stream, river, pond, lake, or wetland.
- The flowpaths for adjacent dispersion devices must be sufficiently spaced to prevent overlap of flows in the flowpath areas.

For sites with on-site sewage disposal systems, the discharge of runoff from dispersion devices must be located downslope of the primary and reserve drainfield areas. This requirement may be waived by the permitting jurisdiction if site topography clearly prevents discharged flows from intersecting the drainfield.

Dispersion devices are not allowed in critical area buffers or on slopes steeper than 20%. Dispersion devices proposed on slopes steeper than 15% or within 50 feet of a geologically hazardous area (RCW 36.70A.030(5) must be approved by a geotechnical engineer or engineering geologist.

The dispersion of runoff must not create flooding or erosion impacts.

Roof Downspouts

Roof surfaces that comply with the Downspout Full Infiltration BMP T5.10A, are considered to be "fully infiltrated" (i.e., zero percent effective imperviousness). All other roof surfaces are considered to be "fully dispersed" (i.e., at or approaching zero percent effective imperviousness) only if they are within a threshold discharge area that is or will be more than 65% forested (or native vegetative cover) and less than 10% impervious (total), AND if they either: 1) comply with the Downspout Dispersion requirements of BMP T5.10B, but with vegetated flow paths of 100 feet or more through the native vegetation preserved area; or 2) disperse the roof runoff along with the road runoff in accordance with the roadway dispersion BMP section below.

Driveway Dispersion

Driveway surfaces are considered to be "fully dispersed" if they are within a threshold discharge area that is or will be more than 65% forested (or native vegetative cover) and less than 10% impervious (total), AND if they either: 1) comply with BMP 5.11 for concentrated flow and BMP T5.12 for sheet flow- and have flow paths of 100 feet or more through native vegetation; or, 2) disperse driveway runoff along with the road runoff in accordance with the roadway dispersion BMP section below.

Roadway Dispersion BMPs

Roadway surfaces are considered to be "fully dispersed" if they are within a threshold discharge area that is or will be more than 65% forested (or native vegetative cover) and less than 10% impervious (total), AND if they comply with the following dispersion requirements:

- The road section shall be designed to minimize collection and concentration of roadway runoff. Sheet flow over roadway fill slopes (i.e., where roadway subgrade is above adjacent right-of-way) should be used wherever possible to avoid concentration.
- When it is necessary to collect and concentrate runoff from the roadway and adjacent upstream areas (e.g., in a ditch on a cut slope), concentrated flows shall be incrementally discharged from the ditch via cross culverts or at the ends of cut sections. These incremental discharges of newly concentrated flows shall not exceed 0.5 cfs at any one discharge point from a ditch for the 100-year runoff event. Where flows at a particular ditch discharge point were already concentrated under existing site conditions (e.g., in a natural channel that crosses the roadway alignment), the 0.5-cfs limit would be in addition to the existing concentrated peak flows.
- Ditch discharge points with up to 0.2 cfs discharge for the peak 100-year flow shall use rock pads or dispersion trenches to disperse flows. Ditch discharge points with between 0.2 and 0.5 cfs discharge for the 100-year peak flow shall use only dispersion trenches to disperse flows.

- Dispersion trenches shall be designed to accept surface flows (free discharge) from a pipe, culvert, or ditch end, shall be aligned perpendicular to the flowpath, and shall be minimum 2 feet by 2 feet in section, 50 feet in length, filled with ¾-inch to 1½-inch washed rock, and provided with a level notched grade board (see Figure 5.5). Manifolds may be used to split flows up to 2 cfs discharge for the 100-year peak flow between up to 4 trenches. Dispersion trenches shall have a minimum spacing of 50 feet between centerlines.
- Flowpaths from adjacent discharge points must not intersect within the 100-foot flowpath lengths, and dispersed flow from a discharge point must not be intercepted by another discharge point. To enhance the flow control and water quality effects of dispersion, the flowpath shall not exceed 15% slope, and shall be located within designated open space. Runoff may be conveyed to an area meeting these flowpath criteria.
- Ditch discharge points shall be located a minimum of 100 feet upgradient of steep slopes (i.e., slopes steeper than 40%), wetlands, and streams.
- Where the Local Plan Approval Authority determines there is a potential for significant adverse impacts downstream (e.g., erosive steep slopes or existing downstream drainage problems), dispersion of roadway runoff may not be allowed, or other measures may be required.

Cleared Area Dispersion BMPs

The runoff from cleared areas that are comprised of bare soil, non-native landscaping, lawn, and/or pasture of up to 25 feet in flow path length can be considered to be "fully dispersed" if it is dispersed through at least 25 feet of native vegetation in accordance with the following criteria:

- The topography of the non-native pervious surface must be such that runoff will not concentrate prior to discharge to the dispersal area.
- Slopes within the dispersal area should be no steeper than 15%.

If the width of the non-native pervious surface is greater than 25 feet, the vegetated flowpath segment must be extended 1 foot for every 3 feet of width beyond 25 feet up to a maximum width of 250 feet.

Minimum Design Requirements for Public Road Projects

Applicability:

These criteria apply to the construction of public roads not within the context of residential, commercial, or industrial site development. They will likely only be implementable on roads outside of the urban growth areas where roadside areas are not planned for urban density development.

<u>Uncollected or natural dispersion into adjacent vegetated areas (i.e., sheet flow into the dispersion area)</u>

Full dispersion credit (i.e. no other treatment or flow control required) for sites that meet the following criteria:

- Outwash soils (Type A sands and sandy gravels, possibly some Type B loamy sands) that
 have an initial saturated hydraulic conductivity rate of 4 inches per hour or greater. The
 saturated hydraulic conductivity must be based on a Pilot Infiltration Test or the Soil Grain
 Size Analysis method as identified in Section 3 of Volume III, or another method as allowed
 by the local government.
 - o Up to 20 feet of impervious flow path needs 10 feet of dispersion area width.
 - o Each additional foot of impervious flow path needs 0.25 feet of dispersion area width.
- Other soils: (Types C and D and some Type B not meeting the outwash soil criteria above)
 - O Dispersion area must have 6.5 feet of width for every 1 foot width of impervious area draining to it. A minimum distance of 100 feet is necessary.
- Criteria applicable to all soil types:
 - o Depth to the average annual maximum ground water elevation should be at least 3 feet.
 - o Impervious surface flow path must be ≤ 75 ft. Pervious flow path must be ≤ 150 ft. Pervious flow paths are up-gradient road side slopes that run onto the road and downgradient road side slopes that precede the dispersion area.
 - Lateral slope of impervious drainage area should be ≤ 8%. Road side slopes must be ≤ 25%. Road side slopes do not count as part of the dispersion area unless native vegetation is re-established and slopes are less than 15%. Road shoulders that are paved or graveled to withstand occasional vehicle loading count as impervious surface.
 - Longitudinal slope of road should be $\leq 5\%$.
 - o Length of dispersion area should be equivalent to length of road.
 - \circ Average longitudinal (parallel to road) slope of dispersion area should be $\leq 15\%$.
 - Average lateral slope of dispersion area should be < 15%.

Channelized (collected and re-dispersed) stormwater into areas with (a) native vegetation or (b) cleared land in areas outside of Urban Growth Areas that do not have a natural or man-made drainage system.

Full dispersion credit (i.e., no other treatment or flow control required) is given to projects that meet the following criteria:

- Outwash soils (Type A sands and sandy gravels, possibly some Type B loamy sands) that
 have an initial saturated hydraulic conductivity rate of 4 inches per hour or greater. The
 saturated hydraulic conductivity must be based on field results using procedures (Pilot
 Infiltration Test or Soil Grain Size Analysis Method) identified in Section 3 of Volume III, or
 another method approved by the local government.
 - O Dispersion area should be at least ½ of the impervious drainage area.
- Other soils: (Types C and D and some Type B not meeting the criterion in 2a above)
 - O Dispersion area must have 6.5 feet of width for every 1 foot width of impervious area draining to it. A minimum distance of 100 feet is necessary.

- Other criteria applicable to all soil types:
 - Depth to the average annual maximum ground water elevation should be at least three feet.
 - o Channelized flow must be re-dispersed to produce longest possible flow path.
 - o Flows must be evenly dispersed across the dispersion area.
 - Flows must be dispersed using rock pads and dispersion techniques as specified under Roadway Dispersion BMPs.
 - Approved energy dissipation techniques may be used.
 - o Limited to on-site (associated with the road) flows.
 - o Length of dispersion area should be equivalent to length of the road.
 - \circ Average longitudinal and lateral slopes of the dispersion area should be $\leq 8\%$.
 - The slope of any flowpath segment must be no steeper than 15% for any 20-foot reach of the flowpath segment.

Engineered dispersion of stormwater runoff into an area with engineered soils

- Full dispersion credit (i.e., no other treatment or flow control required) is given to projects that meet the following criteria:
- Stormwater can be dispersed via sheet flow or via collection and re-dispersion in accordance with the techniques specified under Roadway Dispersion BMPs.
- Depth to the average annual maximum ground water elevation should be at least three feet.
- Type C and D soils must be compost-amended following requirements of BMP T5.13. Dispersion area must meet the 65 to 10 ratio for full dispersion credit.
- Type A and B soils that meet or exceed the 4 inches per hour initial saturated hydraulic conductivity rate minimum must be compost amended in accordance with the requirements of BMP T5.13. Compost must be tilled into the soil in accordance with the guidance document cited above. Up to 20 feet of impervious flow path needs 10 feet of dispersion area width. Each additional foot of impervious flow path needs 0.25 feet of dispersion area width.
- Average longitudinal (parallel to road) slope of dispersion area should be < 15%.
- Average lateral slope of dispersion area should be $\leq 15\%$.
- The dispersion area should be planted with native trees and shrubs.

Other Characteristics for Dispersal areas

Dispersal areas must be outside of the urban growth area; or if inside the urban growth area, in legally protected areas (easements, conservation tracts, public parks).

Native Vegetation Landscape Specifications

These specifications may be used in situations where an applicant wishes to convert a previously developed surface to a native vegetation landscape for purposes of meeting full dispersion requirements or code requirements for forest retention. Native vegetation landscape is intended to have the soil, vegetation, and runoff characteristics approaching that of natural forestland.

Conversion of a developed surface to native vegetation landscape requires the removal of impervious surface, de-compaction of soils, and the planting of native trees, shrubs, and ground cover in compost-amended soil according to all of the following specifications:

- Existing impervious surface and any underlying base course (e.g., crushed rock or gravel) must be completely removed from the conversion area(s).
- Underlying soils must be broken up to a depth of 18 inches. This can be accomplished by
 excavation or ripping with either a backhoe equipped with a bucket with teeth, or a ripper
 towed behind a tractor.
- At least 4 inches of well-decomposed compost must be tilled into the broken up soil as
 deeply as possible. The finished surface should be gently undulating and must be only lightly
 compacted.
- The area of native vegetated landscape must be planted with native species trees, shrubs, and ground cover. Species must be selected as appropriate for site shade and moisture conditions, and in accordance with the following requirements. Note: for landscape areas larger than 10,000 square feet, planting a greater variety of species than the minimum suggested below is strongly encouraged. For example, an acre could easily accommodate three tree species, three species of shrubs, and two or three species of groundcover.
 - Trees: a minimum of two species of trees must be planted, one of which is a conifer.
 Conifer and other tree species must cover the entire landscape area at a spacing recommended by a professional landscaper or in accordance with local requirements.
 - O Shrubs: a minimum of two species of shrubs should be planted. Space plants to cover the entire landscape area, excluding points where trees are planted.
 - Groundcover: a minimum of two species of ground cover should be planted. Space plants so as to cover the entire landscape area, excluding points where trees or shrubs are planted.
- At least 4 inches of hog fuel or other suitable mulch must be placed between plants as mulch for weed control. It is also possible to mulch the entire area before planting; however, an 18-inch diameter circle must be cleared for each plant when it is planted in the underlying amended soil. Note: plants and their root systems that come in contact with hog fuel or raw bark have a poor chance of survival.
- Plantings must be watered consistently once per week during the dry season for the first two years.
- The plantings must be well established on at least 90% of the converted area. A minimum of 90% plant survival is required after 3 years.

Conversion of an area that was under cultivation to native vegetation landscape requires a different treatment. Elimination of cultivated plants, grasses and weeds is required before planting and will be required on an on-going basis until native plants are well-established. The soil should be tilled to a depth of 18 inches. A minimum of 8 inches of soil having an organic content of 6 to 12 percent is required, or a four inch layer of compost may be placed on the surface before planting, or 4 inches of clean wood chips may be tilled into the soil, as recommended by a landscape architect or forester. After soil preparation is complete, continue with steps 4 through 7 above. Placing 4 inches of compost on the surface may be substituted for the hog fuel or mulch. For large areas where frequent watering is not practical, bare-root stock may be substituted at a variable spacing from 10 to 12 feet o.c. (with an average of 360 trees per acre) to allow for natural groupings and 4 to 6 feet o.c. for shrubs. Allowable bare-root stock types are 1-1, 2-1, P-1 and P-2. Live stakes at 4 feet o.c. may be substituted for willow and redosier dogwood in wet areas.

Hydrologic modeling creditsRunoff model representation

Areas that are fully dispersed do not use the WWHM or other approved continuous runoff models. Areas that are fully dispersed do not have to use approved runoff models to demonstrate compliance. They are presumed to fully meet the Runoff Treatment and Flow Control requirements in Minimum Requirements 6 and 7.

5.4 Other BMPs for Low Impact Development

This section contains information about BMPs that, while not required for consideration in compliance with 30.63A.525 SCC, fall into the categories of low impact development BMPs or low impact development as those terms are defined in Snohomish County Code. Some of these BMPs can provide specific hydrologic modeling credits which assist with compliance with the flow control requirements of Minimum Requirement 7.

BMP T5.16: Tree Retention and Tree Planting

Purpose and definition

Trees provide flow control via interception, transpiration, and increased infiltration. Additional environmental benefits include improved air quality, carbon sequestration, reduced heat island effect, pollutant removal, and habitat preservation or formation.

When implemented in accordance with the criteria outlined below, retained and newly planted trees receive credits toward meeting flow control requirements.

The degree of flow control provided by a tree depends on the tree type (i.e., evergreen or deciduous), canopy area, and whether or not the tree canopy overhangs impervious surfaces. Flow control credits may be applied to project sites of all sizes.

Tree retention design criteria

Setbacks of proposed infrastructure from existing trees are critical considerations. Tree protection requirements limit grading and other disturbances in proximity to the tree.

Existing tree species and location must be clearly shown on submittal drawings.

Trees must be viable for long-term retention (i.e., in good health and compatible with proposed construction).

Tree size:

To receive flow control credit, retained trees shall have a minimum 6 inches diameter at breast height (DBH). DBH is defined as the outside bark diameter at 4.5 feet above the ground on the uphill side of a tree. For existing trees smaller than this, the newly planted tree credit may be applied.

The retained tree canopy area shall be measured as the area within the tree drip line. A drip line is the line encircling the base of a tree, which is delineated by a vertical line extending from the outer limit of a tree's branch tips down to the ground. If trees are clustered, overlapping canopies are not double counted.

Tree location:

Flow control credit for retained trees depends upon proximity to ground level impervious or other hard surfaces. To receive a credit, the existing tree must be on the development site and within 20 feet of new and/or replaced ground level impervious or other hard surfaces (e.g., driveway or patio) on the development site. Distance from impervious or other hard surfaces is measured from the tree trunk center.

An arborist report may be required if impervious surface is proposed within the critical root zone of the existing tree. The critical root zone is defined as the line encircling the base of the tree with half the diameter of the dripline. If the arborist report concludes that impervious surface should not be placed within 20 feet of the tree and canopy overlap with impervious surface is still anticipated given a longer setback, the higher tree flow control credit may be approved.

Protection during construction:

The existing tree roots, trunk, and canopy shall be fenced and protected during construction activities.

Retention and protection:

Trees shall be retained, maintained and protected on the site after construction and for the life of the development or until any approved redevelopment occurs in the future. Trees that are removed or die shall be replaced with like species during the next planting season (typically in fall). Trees shall be pruned according to industry standards (ANSI A 300 standards).

Hydrologic modeling credits

Tree retention flow control credits:

Flow control credits for retained trees are set forth below by tree type. These credits can be applied to reduce impervious or other hard surface area requiring flow control. Credits are given as a percentage of the existing tree canopy area. The minimum credit for existing trees ranges from 50 to 100 square feet.

Tree Type	Credit
Evergreen	20% of canopy area (minimum of 100 sq. ft./tree
Deciduous	10% of canopy area (minimum of 50 sq. ft./tree

Impervious/Hard Surface Area Mitigated =

(Σ Evergreen Canopy Area x .2) + (Σ Deciduous Canopy Area x 0.1)

Tree credits are not applicable to trees in native vegetation areas used for flow dispersion or other flow control credit. Credits are also not applicable to trees in planter boxes. The total tree credit for retained and newly planted trees shall not exceed 25 percent of impervious or other hard surface requiring mitigation.

Newly planted tree design criteria

Tree Size:

To receive flow control credit, new deciduous trees at the time of planting shall be at least 1.5 inches in diameter measured 6 inches above the ground. New evergreen trees shall be at least 4 feet tall.

Tree Location:

Trees shall be sited according to sun, soil, and moisture requirements. Planting locations shall be selected to ensure that sight distances and appropriate setbacks are maintained given mature height, size, and rooting depths. Similar to retained trees, flow control credit for newly planted trees depends upon proximity to ground level impervious surfaces. To receive a credit, the tree must be planted on the development site and within 20 feet of new and/or replaced ground level impervious surfaces (e.g., driveway, patio, or parking lot). Distance from impervious surfaces is measured from the edge of the surface to the center of the tree at ground level. To help ensure

tree survival and canopy coverage, the minimum tree spacing for newly planted trees shall accommodate mature tree spread. In no circumstance shall flow control credit be given for new tree density exceeding 10 feet on center spacing.

Plant Material and Planting Specifications

Irrigation:

Provisions shall be made for supplemental irrigation during the first three growing seasons after installation to help ensure tree survival.

Tree retention and protection:

Trees shall be retained, maintained and protected on the site after construction and for the life of the development as required for retained trees.

Newly planted tree flow control credits:

Flow control credits for newly planted trees are set forth below by tree type. These credits can be applied to reduce the impervious or other hard surface area requiring flow control. Credits range from 20 to 50 square feet per tree.

Tree Type	Credit
Evergreen	50 sq. ft. per tree
Deciduous	20 sq. ft. per tree

Impervious/Hard Surface Area Mitigated = Σ Number of Trees x Credit (sq. ft.)

Tree credits are not applicable to trees in native vegetation areas used for flow dispersion or other flow control credit. Credits are also not applicable to trees in planter boxes. The total tree credit for retained and newly planted trees shall not exceed 25 percent of impervious or other hard surface requiring mitigation.

Runoff model representation

If the design criteria for this BMP are followed, the total impervious/hard surface areas entered into the runoff model may be reduced by the amount indicated in the design criteria above.

BMP T5.17: Vegetated Roofs

Vegetated roofs (also known as ecoroofs and green roofs) are thin layers of engineered soil and vegetation constructed on top of conventional flat or sloped roofs. Vegetated roofs can provide stormwater volume reduction and flow attenuation. The range of benefits for a green roof depends on a number of design factors such as plant selection, depth and composition of soil mix, location of the roof, orientation and slope, weather patterns, and the maintenance plan.

All vegetated roofs consist of four basic components: a waterproof membrane, a drainage layer, a light-weight growth medium, and vegetation (see Figure 5.3.7). In addition to these basic components, many systems may also incorporate a protection layer and root barrier to preserve the integrity of the waterproof membrane, a separation/filter layer to stabilize fine particles, capillary mats and mulch/mats to retain moisture and prevent surface erosion due to rain and wind scour.

Applications and limitations

Vegetated roofs are not included in the lists referenced under Minimum Requirement #5. However, they are an option available to project designers who want to use other methods to meet the LID Performance Standard option of Minimum Requirement #5.

While vegetated roofs can be installed on slopes up to 40 degrees, slopes between 5 and 20 degrees (1:12 and 5:12) are most suitable and can provide natural drainage by gravity. Roofs with slopes greater than 10 degrees (2:12) require an analysis of engineered slope stability.

Design criteria

Vegetated roofs must meet all applicable requirements of Snohomish County building codes. The reader is also directed to the 2012 Low Impact Development Technical Guidance Manual for the Puget Sound Basin for a detailed description of vegetated roofs. That document also includes references to other sources of information and design guidance.

Hydrologic modeling credits Runoff model representation

See Appendix III C in Volume III for a summary of how vegetated roofs may be entered into the approved continuous runoff models. When modeling the project using an approved continuous runoff model, use the element intended by the modeling software to represent a vegetated roof. If using WWHM2012, this is the "green roof" element. The user specifies the media thickness, vegetation type, roof slope, and length of drainage within the model.

Maintenance

See the requirements and standards set forth in Chapter 4.6 of this volume, and in Volume VI Stormwater Facility Maintenance.

BMP T5.18: Reverse Slope Sidewalks

Purpose and definition

Reverse slope sidewalks are sloped to drain away from the road and onto adjacent vegetated areas.

Design criteria

- Greater than 10 feet of vegetated surface downslope that is not directly connected into the storm drainage system.
- Vegetated area receiving flow from sidewalk must be native soil or meet guidelines in BMP T5.13.

Hydrologic modeling creditsRunoff model representation

In WWHM 3, enter sidewalk area as lawn/landscaped area over the underlying soil type. For WWHM 2012, see Volume III, Appendix III-C. Use the lateral flow element of an approved continuous runoff hydrologic model to send the impervious area runoff onto the lawn/landscape area that will be used for dispersion. For situations where multiple reverse slope sidewalks will occur the impervious area may be modeled as a landscaped area so that the project schematic in the model is manageable.

BMP T5.19: Minimal Excavation Foundations

Purpose and definition

Low impact foundations are defined as those techniques that do not disturb, or minimally disturb the natural soil profile within the footprint of the structure. This preserves most of the hydrologic properties of the native soil. Pin foundations are an example of a minimal excavation foundation. Minimal excavation foundations are defined as those foundation technologies that engage intact existing soil strength with minimal or no excavation, and do not disturb, or significantly compact the natural soil profile within the footprint of the structure when installed. This preserves most of the hydrologic properties of the native soil. Pin pile, screw pile, and cluster pile foundations are examples of minimal excavation foundations, as well as post and beam, grade beam or fin wall structures.

Applications and limitations

Building foundations must comply with all applicable requirements of Snohomish County development codes

To minimize soil compaction, heavy equipment cannot be used within or immediately surrounding the building. Terracing of the foundation area may be accomplished by tracked, blading equipment not exceeding 650 psf. To minimize soil compaction, heavy equipment, including pile driving equipment that would degrade the natural soil profile's ability to retain, drain and/or filter stormwater cannot be used within or immediately surrounding the building. Tracked equipment weighing 650 psf or less is acceptable.

Hydrologic modeling credits

Where residential roof runoff is dispersed on the up gradient side of a structure in accordance with the design criteria and guidelines in BMP T5.10B, the tributary roof area may be modeled as pasture on the native soil, provided the dispersed runoff is not cut off by an embedded grade beam, wall, or skirt structure from reaching the preserved permeable soils below the building.

Where "step forming" is used on a slope, the square footage of roof that can be modeled as pasture must be reduced to account for lost soils. In "step forming," the building area is terraced in cuts of limited depth. This results in a series of level plateaus on which to erect the form boards. The following equation can be used to reduce the roof area that can be modeled as pasture.

$$A_1 - \underline{dC(.5)} X A_1 = A_2$$

d₽

 A_1 = roof area draining to up gradient side of structure

dC = depth of cuts into the soil profile

dP = permeable depth of soil (The A horizon plus an additional few inches of the B horizon where roots permeate into ample pore space of soil).

 A_2 = roof area that can be modeled as pasture on the native soil

If roof runoff is dispersed down gradient of the structure in accordance with the design criteria and guidelines in BMP T5.10B, AND there is at least 50 feet of vegetated flow path through

native material or lawn/landscape area that meets the guidelines in BMP T5.13, the tributary roof areas may be modeled as lawn/landscaped area.

Where terracing on a slope below the building or vegetated flow path, as defined above, is necessary for construction, the square footage of roof that can be modeled as pasture or lawn/landscaped area must be reduced to account for lost permeable soils. The roof area modeled as pasture or lawn/landscape shall be reduced by the same percentage as that of the permeable soils in the slope below the structure or within the down gradient flow path that are removed by the terracing.

BMP T5.20: Rainwater Harvesting

Purpose and definition

Rainwater harvesting is the capture and storage of rainwater for beneficial use. Roof runoff may be routed to cisterns for storage and nonpotable uses such as irrigation, toilet flushing, and cold water laundry. Rainwater harvesting can help reduce peak stormwater flows, durations, and volumes. The amount of reduction achieved with cistern storage is a function of contributing area, storage volume, and rainwater use rate.

All rainwater harvesting systems must comply with applicable Washington State and Snohomish County regulations.

Design criteria

100% reuse of the annual average runoff volume (use continuous runoff model to get annual average for drainage area)

System designs involving interior uses must have a monthly water balance that demonstrates adequate capacity for each month and reuse of all stored water annually. In order to use the guidance below for Runoff Model Representation, the design must show 100% reuse of the annual average runoff volume. The designer must use an approved continuous runoff hydrologic model to calculate the annual average runoff volume for the drainage area.

System designs involving interior uses must have a monthly water balance that demonstrates adequate capacity for each month and reuse of all stored water annually.

Restrict the use of this BMP to 4 homes/acre housing and lower densities when the captured water is solely for outdoor use.

Hydrologic modeling credits Runoff model representation

Do not enter drainage area into the runoff model. If the design criteria for this BMP are followed, the area draining to the rainwater harvesting BMP is not entered into the runoff model.

Other criteria

Restrict use to 4 homes/acre housing and lower densities when the captured water is solely for outdoor use.

BMP T5.40: Preserving Natural Vegetation

Purpose

Preserving native vegetation on-site to the maximum extent practicable will minimize the impacts of development on stormwater runoff. Note that "preserve natural vegetation (especially forested areas) as much as possible" is one of the design principles required in preparation of the Stormwater Site Plan to meet Minimum Requirement 1, as described in Volume I, Chapter 3 of this manual.

Forest and native growth areas allow rainwater to naturally percolate into the soil, recharging ground water for summer stream flows and reducing surface water runoff that creates erosion and flooding. Conifers can hold up to about 50 percent of all rain that falls during a storm. Twenty to 30 percent of this rain may never reach the ground but evaporates or is taken up by the tree. Forested and native growth areas also may be effective as stormwater buffers around smaller developments.

Application

This BMP can be applied on any development site. On lots that are one acre or greater, preservation of 65 percent or more of the site in native vegetation will allow the use of full dispersion techniques presented in BMP T5.30. Sites that can fully disperse are not required to provide runoff treatment or flow control facilities.

Design guidelines

The preserved area should be situated to minimize the clearing of existing forest cover, to maximize the preservation of wetlands, and to buffer stream corridors.

The preserved area should be clearly marked during clearing and construction on the site

If feasible, the preserved area should be located downslope from the building sites, since flow control and water quality are enhanced by flow dispersion through duff, undisturbed soils, and native vegetation

Hydrologic modeling creditsRunoff model representation

There are no hydrologic modeling credits specific to this BMP in the manner they are specific to other BMPs. However, areas with preserved natural vegetation will almost always produce less modeled runoff than any alternative land surface.

BMP T5.41: Better Site Design

Purpose

Fundamental hydrological concepts and stormwater management concepts can be applied at the site design phase that are more integrated with natural topography, reinforce the hydrologic cycle, often less expensive to build. A few site planning principles help to locate development on the least sensitive portions of a site and accommodate land use while mitigating its impact on stormwater quality. Note that the first three design guidelines are required principles in developing the Stormwater Site Plan in accordance with Volume I, Chapter 3 of this manual.

Design guidelines

Define Development Envelope and Protected Areas

The first step in site planning is to define the development envelope. This is done by identifying protected areas, setbacks, easements and other site features. Site features to be protected may include important existing trees, steep slopes, erosive soils, riparian areas, or wetlands.

By keeping the development envelope compact, environmental impacts can be minimized, construction costs can be reduced, and many of the site's most attractive landscape features can be retained. In some cases, economics or other factors may not allow avoidance of all sensitive areas. In these cases, care can be taken to mitigate the impacts of development through site work and other landscape treatments.

Minimize Directly Connected Impervious Areas

Impervious areas directly connected to the storm drain system are the greatest contributors to urban nonpoint source pollution. As stormwater runoff flows across parking lots, roadways, and other paved areas, the oil, sediment, metals, and other pollutants are collected and concentrated. If this runoff is collected by a drainage structure and carried directly along impervious gutters or in sealed underground pipes, it has no opportunity for filtering by plant material or infiltration into the soil. It also increases in velocity and amount, causing increased peak flows.

A basic site design principle for stormwater management is to minimize these directly connected impervious areas. This can be done by limiting overall impervious land coverage or by infiltrating and/or dispersing runoff from these impervious areas.

Maximize Permeability

Within the development envelope, many opportunities are available to maximize the permeability of new construction. These include minimizing impervious areas, paving with permeable materials, clustering buildings, and reducing the land coverage of buildings by smaller footprints. All of these strategies make more land available for infiltration and dispersion through natural vegetation.

Clustered driveways, small visitor parking bays and other strategies can also minimize the impact of transportation-related surfaces while still providing adequate access.

Once site coverage is minimized through clustering and careful planning, pavement surfaces can be selected for permeability. A patio of brick-on-sand, for example, is more permeable than a

large concrete slab. Engineered soil/landscape systems are permeable ground covers suitable for a wide variety of uses. Permeable/porous pavements can be used in place of traditional concrete or asphalt pavements in many low traffic applications.

Maximizing permeability at every possible opportunity requires the integration of many small strategies. These strategies will be reflected at all levels of a project, from site planning to materials selection. In addition to the environmental and aesthetic benefits, a high-permeability site plan may allow the reduction or elimination of expensive runoff underground conveyance systems, flow control and treatment facilities, yielding significant savings in development costs.

Maximize Choices for Mobility

Given the costs of automobile use, both in land area consumed and pollutants generated, maximizing choices for mobility is a basic principle for environmentally responsible site design. By designing developments to promote alternatives to automobile use, a primary source of stormwater pollution can be mitigated.

Bicycle lanes and paths, secure bicycle parking at community centers and shops, direct, safe pedestrian connections, and transit facilities are all site-planning elements that maximize choices for mobility.

Use Drainage as a Design Element

Unlike conveyance storm drain systems that hide water beneath the surface and work independently of surface topography, a drainage system for stormwater infiltration or dispersion can work with natural land forms and land uses to become a major design element of a site plan.

By applying stormwater management techniques early in the site plan development, the drainage system can suggest pathway alignments, optimum locations for parks and play areas, and potential building sites. In this way, the drainage system helps to generate urban form, giving the development an integral, more aesthetically pleasing relationship to the natural features of the site. Not only does the integrated site plan complement the land, it can also save on development costs by minimizing earthwork and expensive drainage features.

Chapter 6 Pretreatment

6.1 Purpose

This chapter presents the methods that may be used to provide pretreatment prior to basic or enhanced runoff treatment facilities. Pretreatment must be provided in the following applications:

- for sand and media filtration and infiltration BMPs to protect them from excessive siltation and debris, and for bioretention systems if required per BMP 7.30 in this manual; and
- where the basic treatment facility or the receiving water may be adversely affected by non-targeted pollutants (e.g., oil), or may by overwhelmed by a heavy load of targeted pollutants (e.g., suspended solids).

6.2 Application

Presettling basins are a typical pretreatment BMP used to remove suspended solids. All of the basic runoff treatment facilities may also be used for pretreatment to reduce suspended solids. Catch basin inserts may be appropriate in some circumstances to provide oil or TSS control, depending on the type of insert. Some of the manufactured storm drain structures presented in Chapter 12 may also be used for pretreatment for oil or TSS reduction, in accordance with conditions for use set forth by the Washington State Department of Ecology.

A detention pond sized to meet the flow control standard in Volume I may also be used to provide pretreatment for suspended solids removal.

6.3 BMPs for Pretreatment

This Chapter has only one BMP - BMP T6.10 for presettling basins. As noted in Chapter 6.2, there are other BMPs that may also meet the requirements for pretreatment for specific projects.

BMP T6.10 Presettling Basin

Purpose and Definition

A Presettling Basin provides pretreatment of runoff in order to remove suspended solids, which can impact other runoff treatment BMPs.

Application and Limitations

Runoff treated by a Presettling Basin may not be discharged directly to a receiving water; it must be further treated by a basic or enhanced runoff treatment BMP.

Design Criteria

See Snohomish County EDDS Chapter 5-05E.

Setback and separation distances

See setback and separation criteria in SCC 30.63A.710 and Snohomish County EDDS Chapter 5 applicable to the drainage facility of which the presettling basin is a component.

Chapter 7 Infiltration and Bioretention Treatment Facilities

7.1 Purpose

A stormwater infiltration treatment facility is an impoundment; typically a basin, trench, or bioinfiltration swale whose underlying soil removes pollutants from stormwater. Bioretention systems designed without underdrains are also infiltration treatment systems, in which the treatment function is provided both by the bioretention soil mix and also to some extent by the native soil.

Infiltration treatment soils must contain sufficient organic matter and/or clays to sorb, decompose, and/or filter stormwater pollutants. Pollutant/soil contact time, soil sorptive capacity, and soil aerobic conditions are important design considerations.

Volume III, Chapter 3 provides information regarding site criteria, infiltration rates, site suitability, and design details for BMP T7.10 -Infiltration basins, and BMP T7.20 – Infiltration trenches, which may be used to provide treatment for a project if allowed by the treatment BMP selection process set forth in Volume I. The rest of this chapter describes information and requirements for BMP T7.30 – Bioretention systems of various configurations, and BMP T7.40 – Compost-amended vegetated filter strips (CAVFS).

The Underground Injection Control (UIC) regulations of Chapter 173-218 WAC apply to stormwater infiltration systems, although those regulations contain exemptions for various kinds of stormwater infiltration systems. These regulations are implemented by the Washington State Department of Ecology, and Snohomish County recommends that the applicant contact that department for project-specific determinations about UIC regulation applicability. Snohomish County does not implement or enforce the state UIC regulations.

7.2 Application

Infiltration treatment systems are typically installed:

- As off-line systems, or on-line for small drainages
- As a polishing treatment for street/highway runoff after pretreatment for TSS and oil
- As part of a treatment train
- As retrofits at sites with limited land areas, such as residential lots, commercial areas, parking lots, and open space areas.
- With appropriate pretreatment for oil and silt control to prevent clogging. Appropriate pretreatment devices include a pre-settling basin, wet pond/vault, biofilter, constructed wetland, media filter, and oil/water separator.

7.3 Bioretention BMPs

BMP T7.30: Bioretention Cells, Swales, and Planter Boxes

Purpose

To provide effective removal of many stormwater pollutants, and provide reductions in stormwater runoff quantity and surface runoff flow rates. Where the surrounding native soils have adequate infiltration rates, bioretention can help comply with flow control and treatment requirements. Where the native soils have low infiltration rates, underdrain systems can be installed and the facility used to filter pollutants and detain flows that exceed infiltration capacity of the surrounding soil. However, designs utilizing underdrains provide less flow control benefits.

Description

Bioretention areas are shallow landscaped depressions, with a designed soil mix and plants adapted to the local climate and soil moisture conditions, that receive stormwater from a contributing area.

The following terminology is used in this manual:

<u>Bioretention cells:</u> Shallow depressions with a designed planting soil mix and a variety of plant material, including trees, shrubs, grasses, and/or other herbaceous plants. Bioretention cells may or may not have an underdrain and are not designed as a conveyance system.

<u>Bioretention swales:</u> Incorporate the same design features as bioretention cells; however, bioretention swales are designed as part of a system that can convey stormwater when maximum ponding depth is exceeded. Bioretention swales have relatively gentle side slopes and ponding depths that are typically 6 to 12 inches.

Typical cross-sections applicable to these bioretention systems are shown in Figures 5.6 - 5.8.

<u>Bioretention planters and planter boxes:</u> Designed soil mix and a variety of plant material including trees, shrubs, grasses, and/or other herbaceous plants within a vertical walled container usually constructed from formed concrete, but could include other materials. Planter boxes are completely impervious and include a bottom (must include an underdrain). Planters have an open bottom and allow infiltration to the subgrade. These designs are often used in ultra-urban settings. An example is shown in Figure 5.9.

Note: Ecology has approved use of certain patented treatment systems that use specific, high rate media for treatment. Such systems are not considered LID BMPs and are not options for meeting the requirements of Minimum Requirement #5. The Ecology approval is meant to be used for Minimum Requirement #6, where appropriate.

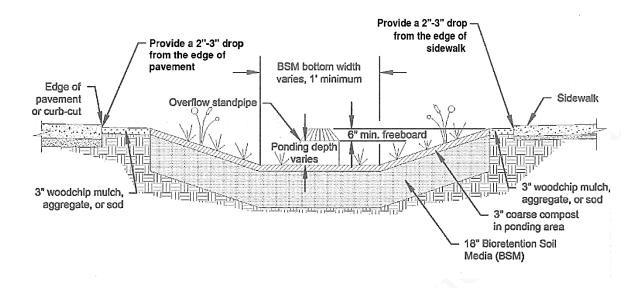


Figure 5.6 –Bioretention System Without Underdrain (Cross Section)

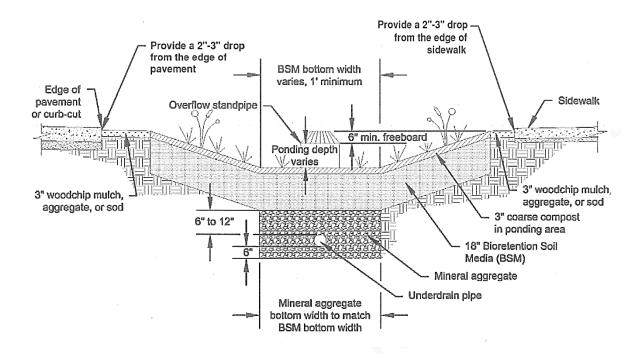


Figure 5.7 –Bioretention System With Underdrain (Cross Section)

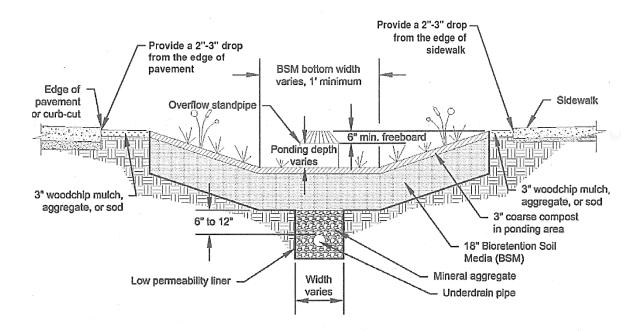


Figure 5.8 –Bioretention System With Liner and Underdrain (Cross Section)

Note: bioretention systems with liners provide stormwater treatment per Minimum Requirement #6, but do not provide credit towards compliance with Minimum Requirement #5 (On-Site Stormwater Management.

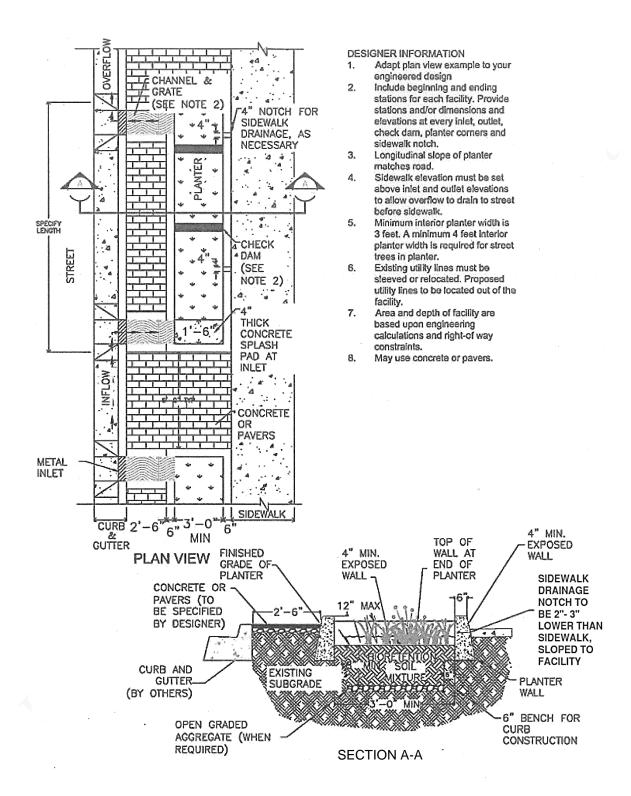


Figure 5.9 – Example of Bioretention Planter

Applications and limitations

Because bioretention facilities use an imported soil mix that has a moderate design infiltration rate, they are best applied for small drainages, and near the source of the stormwater. Cells may be scattered throughout a subdivision; a swale may run alongside the access road; or a series of planter boxes may serve the road. In these situations, they can but are not required to fully meet the requirement to treat 91% of the stormwater runoff file from pollution-generating surfaces. But, the amount of stormwater that is predicted to pass through the soil profile may be estimated and subtracted from the 91% volume that must be treated. Downstream treatment facilities may be significantly smaller as a result.

Bioretention facilities that infiltrate into the ground can also serve a significant flow reduction function. They can but are not required to fully meet the flow control duration standard of Minimum Requirement #7. Because they typically do not have an orifice restricting overflow or underflow discharge rates, they typically don't fully meet Minimum Requirement #7. However, their performance contributes to meeting the standard, and that can result in much smaller flow control facilities at the bottom of the project site. When used in combination with other low impact development techniques, they can also help achieve compliance with the Performance Standard option of Minimum Requirement #5.

Bioretention constructed with imported composted material should not be used within one-quarter mile of phosphorus-sensitive waterbodies if the underlying native soil does not meet the soil suitability criteria for treatment in Volume III, Chapter 3 of this manual. Also, they should also not be used with an underdrain when the underdrain water would be routed to a phosphorus-sensitive receiving water.

Applications with or without underdrains vary extensively and can be applied in new development, redevelopment and retrofits. Typical applications include:

- Individual lots for rooftop, driveway, and other on-lot impervious surface.
- Shared facilities located in common areas for individual lots.
- Areas within loop roads or cul-de-sacs.
- Landscaped parking lot islands.
- Within right-of-ways along roads (often linear bioretention swales and cells).
- Common landscaped areas in apartment complexes or other multifamily housing designs.
- Planters on building roofs, patios, and as part of streetscapes.

Infeasibility criteria

The following criteria describe conditions that make bioretention or rain gardens not required. If a project proponent wishes to use a bioretention or rain garden BMP though not required to because of these feasibility criteria, they may propose a functional design to the local government. Note: Criteria with setback distances are as measured from the edge of the bioretention soil mix.

Citation of any of the following infeasibility criteria must be based on an evaluation of site-specific conditions and a written recommendation from an appropriate licensed professional (e.g., engineer, geologist, hydrogeologist):

- Where professional geotechnical evaluation recommends infiltration not be used due to reasonable concerns about erosion, slope failure, or down gradient flooding.
- Within an area whose ground water drains into an erosion hazard, or landslide hazard area.
- Where the only area available for siting would threaten the safety or reliability of pre-existing underground utilities, pre-existing underground storage tanks, pre-existing structures, or preexisting road or parking lot surfaces.
- Where the only area available for siting does not allow for a safe overflow pathway to the municipal separate storm sewer system or private storm sewer system.
- Where there is a lack of usable space for rain garden/bioretention facilities at re-development sites, or where there is insufficient space within the existing public right-of-way on public road projects.
- Where infiltrating water would threaten existing below grade basements.
- Where infiltrating water would threaten shoreline structures such as bulkheads.

The following criteria can be cited as reasons for a finding of infeasibility without further justification (though some require professional services):

- Within setbacks from structures as established by the local government with jurisdiction.
- Where they are not compatible with surrounding drainage system as determined by the local government with jurisdiction (e.g., project drains to an existing stormwater collection system whose elevation or location precludes connection to a properly functioning bioretention facility).
- Where land for bioretention is within area designated as an erosion hazard, or landslide hazard.
- Where the site cannot be reasonably designed to locate bioretention facilities on slopes less than 8%.
- Within 50 feet from the top of slopes that are greater than 20% and over 10 feet of vertical relief.
- For properties with known soil or ground water contamination (typically federal Superfund sites or state cleanup sites under the Model Toxics Control Act (MTCA)):
 - Within 100 feet of an area known to have deep soil contamination;
 - Where ground water modeling indicates infiltration will likely increase or change the direction of the migration of pollutants in the ground water;
 - Wherever surface soils have been found to be contaminated unless those soils are removed within 10 horizontal feet from the infiltration area;
 - Any area where these facilities are prohibited by an approved cleanup plan under the state Model Toxics Control Act or Federal Superfund Law, or an environmental covenant under Chapter 64.70 RCW.
- Within 100 feet of a closed or active landfill.

- Within 100 feet of a drinking water well, or a spring used for drinking water supply.
- Within 10 feet of small on-site sewage disposal drainfield, including reserve areas, and grey water reuse systems. For setbacks from a "large on-site sewage disposal system," see Chapter 246-272B WAC.
- Within 10 feet of an underground storage tank and connecting underground pipes when the capacity of the tank and pipe system is 1100 gallons or less. (As used in these criteria, an underground storage tank means any tank used to store petroleum products, chemicals, or liquid hazardous wastes of which 10% or more of the storage volume (including volume in the connecting piping system) is beneath the ground surface.
- Within 100 feet of an underground storage tank and connecting underground pipes when the capacity of the tank and pipe system is greater than 1100 gallons.
- Where the minimum vertical separation of 1 foot to the seasonal high water table, bedrock, or other impervious layer would not be achieved below bioretention or rain gardens that would serve a drainage area that is: 1) less than 5,000 sq. ft. of pollution-generating impervious surface, and 2) less than 10,000 sq. ft. of impervious surface; and, 3) less than 3/4 acres of pervious surface.
- Where the a minimum vertical separation of 3 feet to the seasonal high water table, bedrock or other impervious layer would not be achieved below bioretention that: 1) would serve a drainage area that meets or exceeds: a) 5,000 square feet of pollution-generating impervious surface, or b) 10,000 square feet of impervious surface, or c) three-quarter (3/4) acres of pervious surfaces; and 2) cannot reasonably be broken down into amounts smaller than indicated in (1).
- Where the field testing indicates potential bioretention/rain garden sites have a measured (a.k.a., initial) native soil saturated hydraulic conductivity less than 0.30 inches per hour. If the measured native soil infiltration rate is less than 0.30 in/hour, this option should not be used to meet the requirements of MR_#5. In these slow draining soils, a bioretention facility with an underdrain may be used to treat pollution- generating surfaces to help meet Minimum Requirement #6, Runoff Treatment. If the underdrain is elevated within a base course of gravel, the bioretention system will also provide some modest flow reduction benefit that will help achieve Minimum Requirement #7.

Other site suitability factors

<u>Utility conflicts</u>: Consult Snohomish County requirements for horizontal and vertical separation required for publicly-owned utilities, such as water and sewer. Consult the appropriate franchise utility owners for separation requirements from their utilities, which may include communications and gas. When separation requirements cannot be met, designs should include appropriate mitigation measures, such as impermeable liners over the utility, sleeving utilities, fixing known leaky joints or cracked conduits, and/or adding an underdrain to the bioretention.

<u>Transportation safety</u>: The design configuration and selected plant types should provide adequate sight distances, clear zones, and appropriate setbacks for roadway applications in accordance with Snohomish County requirements.

<u>Ponding depth and surface water draw-down</u>: Flow control needs, as well as location in the development, and mosquito breeding cycles will determine draw-down timing. For example, front yards and entrances to residential or commercial developments may require rapid surface dewatering for aesthetics.

<u>Impacts of surrounding activities</u>: Human activity influences the location of the facility in the development. For example, locate bioretention areas away from traveled areas on individual lots to prevent soil compaction and damage to vegetation or provide elevated or bermed pathways in areas where foot traffic is inevitable, and provide barriers, such as wheel stops, to restrict vehicle access in roadside applications.

<u>Visual buffering</u>: Bioretention facilities can be used to buffer structures from roads, enhance privacy among residences, and for an aesthetic site feature.

<u>Site growing characteristics and plant selection</u>: Appropriate plants should be selected for sun exposure, soil moisture, and adjacent plant communities. Native species or hardy cultivars are recommended and can flourish in the properly designed and placed Bioretention Soil Mix with no nutrient or pesticide inputs and 2-3 years irrigation for establishment. Invasive species control may be necessary.

Field and design procedures

Determining subgrade infiltration rates

Follow requirement and procedures set forth in Volume I, Chapters 2 and 3, and Volume III, Chapter 3.3.10 of this manual.

Determining Bioretention soil mix infiltration rate

The WWHM's default infiltration rate of 12 inches per hour may be used for the Bioretention Soil Mix recommended herein.

If creating a custom bioretention soil mix, Use ASTM D 2434 Standard Test Method for Permeability of Granular Soils (Constant Head) with a compaction rate of 85 percent using ASTM D1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort. See Appendix V-B for specific procedures for conducting ASTM D 2434. The WWHM user must enter the derived value into WWHM using "View/Edit Soil Types" pull down menu and adjusting the Ksat value. The designer must enter the derived Ksat value into the approved continuous runoff hydrologic model.

Determine the appropriate safety factor for the saturated hydraulic conductivity (Ksat). If the contributing area of the bioretention cell or swale is equal to or exceeds any of the following limitations, use 4 as the infiltration rate (Ksat) safety factor:

- 5,000 square feet of pollution-generating impervious surface;
- 10,000 square feet of impervious surface; or
- ¾ acre of lawn and landscape.

Design Criteria for Bioretention

Flow entrance and presettling

Flow entrance design will depend on topography, flow velocities and volume entering the pretreatment and bioretention area, adjacent land use and site constraints. Flow velocities entering bioretention should be less than 1.0 ft/second to minimize erosion potential. Five primary types of flow entrances can be used for bioretention:

1. 1. Dispersed, low velocity flow across a landscape area:

Landscape areas and vegetated buffer strips slow incoming flows and provide an initial settling of particulates and are the preferred method of delivering flows to the bioretention cell. Dispersed flow may not be possible given space limitations or if the facility is controlling roadway or parking lot flows where curbs are mandatory.

2. 2. Dispersed or sheet flow across pavement or gravel and past wheel stops for parking areas.

For roadside, driveway or parking lot areas, curb cuts should include a rock pad, concrete or other erosion protection material in the channel entrance to dissipate energy. Minimum curb cut width should be 12 inches; however, 18 inches is recommended. Avoid the use of angular rock or quarry spalls and instead use round (river) rock if needed. Removing sediment from angular rock is difficult. Flow entrance should drop 2 to 3 inches from curb line and provide an area for settling and periodic removal of sediment and coarse material before flow dissipates to the remainder of the cell.

Curb cuts used for bioretention areas in high use parking lots or roadways require increased level of maintenance due to high coarse particulates and trash accumulation in the flow entrance and associated bypass of flows. The following are methods recommended for areas where heavy trash and coarse particulates are anticipated:

- Curb cut width: 18 inches.
- At a minimum the flow entrance should drop 2 to 3 inches from gutter line into the bioretention area and provide an area for settling and periodic removal of debris.
- Catch basins or forebays may be necessary at the flow entrance to adequately capture
 debris and sediment load from large contributing areas and high use areas. Piped flow
 entrance in this setting can easily clog and catch basins with regular maintenance are
 necessary to capture coarse and fine debris and sediment.
- 3. 3.—Pipe flow entrance:

Piped entrances should include rock or other erosion protection material in the channel entrance to dissipate energy and disperse flow.

4. 4. Catch basin:

In some locations where road sanding or higher than usual sediment inputs are anticipated, catch basins can be used to settle sediment and release water to the bioretention area through a grate for filtering coarse material.

5. 5. Trench drains:

Trench drains can be used to cross sidewalks or driveways where a deeper pipe conveyance creates elevation problems. Trench drains tend to clog and may require additional maintenance.

Woody plants can restrict or concentrate flows and can be damaged by erosion around the root ball and should not be placed directly in the entrance flow path.

Bottom area and side slopes

Bioretention areas are highly adaptable and can fit various settings such as rural and urban roadsides, ultra urban streetscapes and parking lots by adjusting bottom area and side slope configuration. Recommended maximum and minimum dimensions include:

- Maximum planted side slope if total cell depth is greater than 3 feet: 3H:1V. If steeper side slopes are necessary rockeries, concrete walls or soil wraps may be effective design options. See Snohomish County EDDS Chapter 4-16 for safety railing standards at bicycle and pedestrian facilities adjacent to steep slopes.
- Minimum bottom width for bioretention swales: 2 feet recommended and 1 foot minimum. Carefully consider flow depths and velocities, flow velocity control (check dams) and appropriate vegetation or rock mulch to prevent erosion and channelization at bottom widths less than 2 feet.

Bioretention areas should have a minimum shoulder of 12 inches (30.5 cm) between the road edge and beginning of the bioretention side slope where flush curbs are used. Compaction for the shoulder should be 90%.

Ponding area

Ponding depth recommendations:

- Maximum ponding depth: 12 inches (30.5 cm).
- Surface pool drawdown time: 24 hours

For design on projects subject to Minimum Requirement #5, and choosing to use List #1 or List #2 of that requirement, a bioretention facility shall have a horizontally projected surface area below the overflow which is at least 5% of the total impervious surface area draining to it. If lawn/landscape area will also be draining to the bioretention facility, the bioretention facility's horizontally projected surface area below the overflow shall be increased by 2% of the lawn/landscape area.

Maximum designed depth of ponding (before surface overflow to a pipe or ditch) must be considered in light of drawdown time.

For bioretention areas with underdrains, elevating the drain to create a temporary saturated zone beneath the drain is advised to promote denitrification and prolong moist soil conditions for plant survival during dry periods (see Underdrain section below for details).

Surface overflow

Surface overflow can be provided by vertical stand pipes that are connected to underdrain systems, by horizontal drainage pipes or armored overflow channels installed at the designed maximum ponding elevations. Overflow can also be provided by a curb cut at the down-gradient end of the bioretention area to direct overflows back to the street. Overflow conveyance structures are necessary for all bioretention facilities to safely convey flows that exceed the capacity of the facility and to protect downstream natural resources and property.

The minimum freeboard from the invert of the overflow stand pipe, horizontal drainage pipe or earthen channel shall be 6 inches.

Default Bioretention Soil Media (BSM)

Projects which use the following requirements for the bioretention soil media do not have to test the media for it saturated hydraulic conductivity. They may assume the rates specified in the subsection titled "Determining Bioretention Soil Mix Infiltration Rate."

1. 1.—Mineral aggregate

Percent Fines: A range of 2 to 4 percent passing the #200 sieve is ideal and fines should not be above 5 percent for a proper functioning specification according to ASTM D422.

2. 2.—Aggregate gradation

The aggregate portion of the BSM should be well-graded. According to ASTM D 2487-98 (Classification of Soils for Engineering Purposes (Unified Soil Classification System)), well-graded sand should have the following gradation coefficients:

- Coefficient of Uniformity ($C_u = D_{60}/D_{10}$) equal to or greater than 4, and
- Coefficient of Curve ($C_c = (D_{30})^2/D_{60} \times D_{10}$) greater than or equal to 1 and less than or equal to 3.

The following gradation provides a guideline for the aggregate component of a Bioretention Soil Mix specification in western Washington. The sand gradation below is often supplied as a well-graded utility or screened. With compost this blend provides enough fines for adequate water retention, hydraulic conductivity within recommended range (see below), pollutant removal capability, and plant growth characteristics for meeting design guidelines and objectives.

Sieve Size	Percent Passing
3/8"	<u>100</u>
<u>#4</u>	95-100
<u>#10</u>	<u>75-90</u>
<u>#40</u>	<u>25-40</u>
#100	4-10
#200	<u>2-5</u>

Sieve Size	Percent Passing
3/8"	100
#4	95-100
#10	75-90
#40	25-40
	4.10
#100	4-10
#200	2-3

Where existing soils meet the above aggregate gradation, those soils may be amended rather than importing mineral aggregate.

- 3. 3.—Compost to Aggregate Ratio, Organic Matter Content, Cation Exchange Capacity
 - Compost to aggregate ratio: 60-65 percent mineral aggregate, 35 40 percent compost by volume.
 - Organic matter content: 5 8 percent by weight.
 - Cation Exchange Capacity (CEC) must be ≥ 5 milliequivalents/100 g dry soil Note: Soil mixes meeting the above specifications do not have to be tested for CEC. They will readily meet the minimum CEC.

4. **4.**—Compost

To ensure that the BSM will support healthy plant growth and root development, contribute to biofiltration of pollutants, and not restrict infiltration when used in the proportions cited herein, the following compost standards are required:

- Meets the definition of "composted material" in WAC 173-350-100 and complies with testing standards and other parameters in WAC 173-350-220
- Produced at a composting facility that is permitted by the Snohomish Health District. Contact the Snohomish Health District at www.snohd.org.
- The compost product must originate a minimum of 65 percent by volume from recycled plant waste composed of "yard debris," "crop residues," and "bulking agents" as those terms are defined in WAC 173-350-100. A maximum of 35 percent by volume of "post-consumer food waste" as defined in WAC 173-350-100, but not including biosolids, may be substituted for recycled plant waste.
- Stable (low oxygen use and CO₂ generation) and mature (capable of supporting plant growth) by tests shown below. This is critical to plant success in a bioretention soil mixes.
- Moisture content range: no visible free water or dust produced when handling the material.
- Tested in accordance with the U.S. Composting Council Test Method for the Examination of Compost and Composting" (TMECC), as established in the Composting Council's "Seal of Testing Assurance" (STA) program. Most Washington compost facilities now use these tests.
- Screened to the following size gradations for Fine Compost when tested in accordance with TMECC test method 02.02-B Sample Sieving for Aggregate Size Classification.
- Fine Compost shall meet the following gradation by dry weight:
 - o Minimum percent passing 2" 100%
 - o Minimum percent passing 1" 99%
 - o Minimum percent passing 5/8" 90%
 - Minimum percent passing ¼" 75%
- pH between 6.0 and 8.5 (TMECC 04.11-A).

- "Physical contaminants" (as defined in WAC 173-350-100) content less that 1% by weight (TMECC 03.08-A), not to exceed 0.25% film plastic by dry weight.
- Minimum organic matter content of 40% (TMECC 05.07-A Loss on Ignition)
- Soluble salt content less than 4.0 dS/m (mmhos/cm) (TMECC 04.10-A Electrical Conductivity, 1:5 Slurry Method, Mass Basis)
- Maturity indicators from a cucumber bioassay (TMECC 05.05-A Seedling Emergence and Relative Growth) must be greater than 80% for both emergence and vigor.
- Stability of 7 mg CO₂–C OM/day or below (TMECC 05.08-B "Carbon Dioxide Evolution Rate")
- Carbon to nitrogen ratio of less than 25:1 based on TMECC 05.02A Carbon To Nitrogen Ratio (which uses 04.01 Organic Carbon and 04.02D Total Nitrogen by Oxidation). The C:N ratio may be up to 35:1 for plantings composed entirely of Puget Sound Lowland native species and up to 40:1 for coarse compost to be used as a surface mulch (not in a soil mix).

Design Criteria for Custom Bioretention Soil Mixes

Projects which prefer to create a custom Bioretention Soil Mix rather than using the default requirements above must demonstrate compliance with the following criteria using the specified test method:

- CEC \geq 5 meq/100 grams of dry soil; USEPA 9081
- pH between 5.5 and 7.0
- 5 8 percent organic matter content before and after the saturated hydraulic conductivity test;
 ASTM D2974(Standard Test Method for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils)
- 2-5 percent fines passing the 200 sieve; TMECC 04.11-A
- Measured (Initial) saturated hydraulic conductivity of less than 12 inches per hour; ASTM D 2434 (Standard Test Method for Permeability of Granular Soils (Constant Head)) at 85% compaction per ASTM D 1557 (Standard Test Method s for Laboratory Compaction Characteristics of Soil Using Modified Effort). Also, use Appendix V-B, Recommended Procedures for ASTM D 2434 When Measuring Hydraulic Conductivity for Bioretention Soil Mixes.
- Design (long-term) saturated hydraulic conductivity of more than 1 inch per hour. Note: Design saturated hydraulic conductivity is determined by applying the appropriate infiltration correction factors as explained above under "Determining bioretention soil mix infiltration rate."
- If compost is used in creating the custom mix, it must meet all of the specifications listed above for compost, except for the gradation specification. An alternative gradation specification must indicate the minimum percent passing for a range of similar particle sizes

Soil Depth:

Soil depth must be a minimum of 18 inches to provide water quality treatment and good growing conditions for selected plants

Filter Fabrics:

Do not use filter fabrics between the subgrade and the Bioretention Soil Mix. The gradation between existing soils and Bioretention Soil Mix is not great enough to allow significant migration of fines into the Bioretention Soil Mix. Additionally, filter fabrics may clog with downward migration of fines from the Bioretention Soil Mix.

Underdrain (optional):

Where the underlying soils have an estimated initial infiltration rate of 0.3-0.6 inches per hour, bioretention facilities without an underdrain, or with an elevated underdrain directed to a surface outlet, may be used to satisfy List #2the list approach of Minimum Requirement #5. Underdrained bioretention facilities that drain to a retention/detention facility must meet the following criteria if they are used to satisfy list #2the list approach of Minimum Requirement #5:

- the invert of the underdrain must be elevated 6 inches above the bottom of the aggregate bedding layer. A larger distance between the underdrain and bottom of the bedding layer is desirable, but cannot be used to trigger infeasibility due to inadequate vertical separation to the seasonal high water table, bedrock, or other impermeable layer.
- the distance between the bottom of the bioretention soil mix and the crown of the underdrain pipe must be not less than 6 but not more than 12 inches;
- the aggregate bedding layer must run the full length and the full width of the bottom of the bioretention facility;
- the facility must not be underlain by a low permeability liner that prevents infiltration into the native soil.

Figure 5.7 depicts a bioretention facility with an elevated underdrain. Figure 5.8 depicts a bioretention facility with an underdrain and a low permeability liner. The latter is not considered a low impact development BMP. It cannot be used to implement List #2the list approach of Minimum Requirement #5.

The void volume of the aggregate below the invert of the underdrain and above the bottom of the bioretention facility can be used in the WWHM or MGSFlood for dead storage volume that provides flow control benefit. Assume a 40% void volume for the Type 26 mineral aggregate specified below.

Underdrain systems should only be installed when the bioretention facility is:

- Located near sensitive infrastructure (e.g., unsealed basements) and potential for flooding is likely.
- Used for filtering storm flows from gas stations or other pollutant hotspots (requires impermeable liner).
- Located above native soils with infiltration rates that are not adequate to meet maximum pool and system dewater rates, or are below a minimum rate allowed by the local government.

• In an area that does not provide the minimum depth to a hydraulic restriction layer, e.g., high seasonal ground water.

The underdrain can be connected to a downstream open conveyance (bioretention swale), to another bioretention cell as part of a connected treatment system, daylight to a dispersion area using an effective flow dispersion practice, or to a storm drain.

Underdrain Pipe

Underdrains shall be slotted, thick-walled plastic pipe. The slot opening should be smaller than the smallest aggregate gradation for the gravel filter bed (see underdrain filter bed below) to prevent migration of material into the drain. This configuration allows for pressurized water cleaning and root cutting if necessary.

Underdrain pipe recommendations:

- Minimum pipe diameter: 4 inches (pipe diameter will depend on hydraulic capacity required, 4 to 8 inches is common).
- Slotted subsurface drain PVC per ASTM D1785 SCH 40.
- Slots should be cut perpendicular to the long axis of the pipe and be 0.04 to 0.069 inches by 1 inch long and be spaced 0.25 inches apart (spaced longitudinally). Slots should be arranged in four rows spaced on 45-degree centers and cover ½ of the circumference of the pipe. See Filter Materials section for aggregate gradation appropriate for this slot size.
- Underdrains should be sloped at a minimum of 0.5 percent unless otherwise specified by an engineer.

Perforated PVC or flexible slotted HDPE pipe cannot be cleaned with pressurized water or root cutting equipment, are less durable and are not recommended. Wrapping the underdrain pipe in filter fabric increases chances of clogging and is not recommended. A 6-inch rigid non-perforated observation pipe or other maintenance access should be connected to the underdrain every 250 to 300 feet to provide a clean-out port, as well as an observation well to monitor dewatering rates.

Underdrain Aggregate Filter and Bedding Layer

Aggregate filter and bedding layers buffer the under-drain system from sediment input and clogging. When properly selected for the soil gradation, geosynthetic filter fabrics can provide adequate protection from the migration of fines. However, aggregate filter and bedding layers, with proper gradations, provide a larger surface area for protecting underdrains and are preferred.

Guideline for underdrain aggregate filter and bedding layers with heavy walled slotted pipe (see underdrain pipe guideline above):

Sieve Size	Percent Passing
3/4 inch3/8"	<u>100</u>

½ inch #4	<u>30-60</u>
<u>US No. 8#10</u>	<u>20-50</u>
<u>US No. 50#40</u>	<u>3-12</u>
<u>US No.</u> 200#100	0-1

Sieve size	Percent Passing
3/4 inch	100
¼ inch	30-60
US No. 8	20-50
US No. 50	3-12
US No. 200	0-1

The above gradation is a Type 26 mineral aggregate.

Place underdrain on a bed of the Type 26 aggregate with a minimum thickness of 6 inches and cover with Type 26 aggregate to provide a 1-foot minimum depth around the top and sides of the slotted pipe.

Orifice and other flow control structures:

The minimum orifice diameter should be 0.5 inches to minimize clogging and maintenance requirements.

Check dams and weirs

See BMP T9.20 – Wet Biofiltration Swale.

Hydraulic restriction layers:

Adjacent roads, foundations or other infrastructure may require that infiltration pathways are restricted to prevent excessive hydrologic loading. Two types of restricting layers can be incorporated into bioretention designs:

- Clay (bentonite) liners are low permeability liners. Where clay liners are used underdrain systems are necessary. See Chapter 4.4 of this volume for details.
- Geomembrane liners completely block infiltration to subgrade soils and are used for ground water protection when bioretention facilities are installed to filter storm flows from pollutant hotspots or on sidewalls of bioretention areas to restrict lateral flows to roadbeds or other sensitive infrastructure. Where geomembrane liners are used to line the entire facility

underdrain systems are necessary. The liner should have a minimum thickness of 30 mils and be ultraviolet (UV) resistant.

Plant materials

In general, the predominant plant material utilized in bioretention systems are facultative species adapted to stresses associated with wet and dry conditions. Soil moisture conditions will vary within the facility from saturated (bottom of cell) to relatively dry (rim of cell). Accordingly, wetland plants may be used in the lower areas, if saturated soil conditions exist for appropriate periods, and drought-tolerant species planted on the perimeter of the facility or on mounded areas. See Appendix 1 of the 2012 Low Impact Development Technical Guidance Manual for Puget Sound for recommended plant species for bioretention facilities.

Mulch layer

Bioretention systems may include a mulch layer. If used, mulch shall be:

- Coarse compost in the bottom of the facilities (compost is less likely to float during cell inundation). Compost shall not include biosolids or manure.
- Shredded or chipped hardwood or softwood on side slopes above ponding elevation and rim
 area. Arborist mulch is mostly woody trimmings from trees and shrubs and is a good source
 of mulch material. Wood chip operations are a good source for mulch material that has more
 control of size distribution and consistency. Do not use shredded construction wood debris or
 any shredded wood to which preservatives have been added.
- Free of weed seeds, soil, roots and other material that is not bole or branch wood and bark.
- A maximum of 2 to 3 inches thick.

Mulch shall not be:

- Grass clippings (decomposing grass clippings are a source of nitrogen and are not recommended for mulch in bioretention areas).
- Pure bark (bark is essentially sterile and inhibits plant establishment).

In bioretention areas where higher flow velocities are anticipated an aggregate mulch may be used to dissipate flow energy and protect underlying Bioretention Soil Mix. Aggregate mulch varies in size and type, but 1 to 1½ 1-1/2 inch gravel (rounded) decorative rock is typical.

Setback and separation requirements

Setback and separation distances shall be in accordance with SCC 30.63A.710 and Snohomish County EDDS Chapter 5-12.

Installation

Excavation

Soil compaction can lead to facility failure; accordingly, minimizing compaction of the base and sidewalls of the bioretention area is critical. Excavation should never be allowed during wet or saturated conditions (compaction can reach depths of 2-3 feet during wet conditions and mitigation is likely not be possible). Excavation should be performed by machinery operating adjacent to the bioretention facility and no heavy equipment with narrow tracks, narrow tires, or large lugged, high pressure tires should be allowed on the bottom of the bioretention facility. If machinery must operate in the bioretention cell for excavation, use light weight, low ground-contact pressure equipment and rip the base at completion to refracture soil to a minimum of 12 inches. If machinery operates in the facility, subgrade infiltration rates must be field tested and compared to design rates. Failure to meet or exceed the design infiltration rate will require revised engineering designs to verify achievement of treatment and flow control benefits that were estimated in the Stormwater Site Plan.

Prior to placement of the BSM, the finished subgrade shall:

- Be scarified to a minimum depth of 3 inches.
- Have any sediment deposited from construction runoff removed. To remove all introduced sediment, subgrade soil should be removed to a depth of 3-6 inches and replaced with BSM.
- Be inspected by the responsible engineer to verify required subgrade condition.
- Sidewalls of the facility, beneath the surface of the BSM, can be vertical if soil stability is adequate. Exposed sidewalls of the completed bioretention area with BSM in place should be no steeper than 3H:1V. The bottom of the facility should be flat.

Soil Placement

On-site soil mixing or placement shall not be performed if Bioretention Soil Mix or subgrade soil is saturated. The bioretention soil mixture should be placed and graded by machinery operating adjacent to the bioretention facility. If machinery must operate in the bioretention cell for soil placement, use light weight equipment with low ground-contact pressure. If machinery operates in the facility, subgrade infiltration rates must be field tested and compared to design rates. Failure to meet or exceed the design infiltration rate will require revised engineering designs to

verify achievement of treatment and flow control benefits that were estimated in the Stormwater Site Plan.

The soil mixture shall be placed in horizontal layers not to exceed 12 inches per lift for the entire area of the bioretention facility.

Compact the Bioretention Soil Mix to a relative compaction of 85 percent of modified maximum dry density (ASTM D 1557). Compaction can be achieved by boot packing (simply walking over all areas of each lift), and then apply 0.2 inches (0.5 cm) of water per 1 inch (2.5 cm) of Bioretention Soil Mix depth. Water for settling should be applied by spraying or sprinkling.

Hydrologic modeling for bioretention systems Runoff model representation

Model bioretention systems as infiltration systems using WWHM2012 version 4.2.16 and appropriate soil and hydraulic conductivity data developed as part of the Stormwater Site Plan, according to the requirements of Volume III, Chapter 3.3.10, and using the specified methods and parameters from Volume III Appendix III-C for the specific biofiltration facility type and hydrologic model used (WWHM3 or WWHM 2012). MGSFlood may not be used for design of bioretention systems. Multiple bioretention facilities with similar designs (i.e., soil depth, ponding depth, freeboard height, and drainage area to ponding area ratio), and infiltration rates (within a factor of 2) may be represented in the model as a single bioretention system with the following characteristics:

- drainage area = combined drainage areas of the individual systems;
- ponded area = combined ponded areas of the individual systems;
- design infiltration rate = weighted average design infiltration rate, weighted by size of drainage area.

For bioretention with slide slopes of 3H:1V or flatter, the applicant may model infiltration through the side slopes to the native soil. In WWHM, this is done by switching the default setting for "Use Wetted Surface Area (sidewalls)" from NO to YES.

Note that if the project is using bioretention to only meet the BMP list approach within Minimum Requirement 5, there is no need to model the bioretention in a continuous runoff model. Size the bioretention as described above in *Ponding area*.

The guidance below is to show compliance with the LID Performance Standard in Minimum Requirement 5, or the standards in Minimum Requirements 6, 7, and/or 8.

Approved continuous runoff modeling software include modeling elements for bioretention.

MGS Flood shall not be used for design of bioretention systems.

The equations used by the elements are intended to simulate the wetting and drying of soil as well as how the soils function once they are saturated. This group of LID elements uses the modified Green Ampt equation to compute the surface infiltration into the amended soil. The water then moves through the top amended soil layer at the computed rate, determined by Darcy's and Van Genuchten's equations. As the soil approaches field capacity (i.e., gravity head is greater than matric head), the model determines when water will begin to infiltrate into the second soil layer (lower layer). This occurs when the matric head is less than the gravity head in the first layer (top layer). The second layer is intended to prevent loss of the amended soil layer.

As the second layer approaches field capacity, the water begins to move into the third layer – the gravel underlayer. For each layer, the user inputs the depth of the layer and the type of soil.

Within the WWHM continuous runoff model, for the Ecology-recommended soil specifications for each layer in the design criteria for bioretention, the model will automatically assign predetermined appropriate values for parameters that determine water movement through that soil. These include: wilting point, minimum hydraulic conductivity, maximum saturated hydraulic conductivity, and the Van Genuchten number.

For bioretention with underlying perforated drain pipes that discharge to the surface, the only volume available for storage (and modeled as storage as explained herein) is the void space within the aggregate bedding layer below the invert of the drain pipe. Use 40% void space for the Type 26 mineral aggregate described above

It is preferable to enter each bioretention device and its drainage area into the approved computer models for estimating their performance. However, where site layouts involve multiple bioretention facilities, the modeling schematic can become extremely complicated or not accommodated by the available schematic grid. In those cases, multiple bioretention facilities with similar designs (i.e., soil depth, ponding depth, freeboard height, and drainage area to ponding area ratio), and infiltration rates (within a factor of 2) may have their drainage areas and ponded areas combined and represented in the runoff model as one drainage area and one bioretention device. In this case, use a weighted average of the design infiltration rates at each location. The averages are weighted by the size of their drainage areas.

For bioretention with slide slopes of 3H:1V or flatter, infiltration through the side slope areas can be significant. Where side slopes are 3H:1V or flatter, bioretention can be modeled allowing infiltration through the side slope areas to the native soil. In WWHM, modeling of infiltration through the side slope areas is accomplished by switching the default setting for "Use Wetted Surface Area (sidewalls): from "NO" to "YES."

Protection of bioretention facilities during construction

Bioretention facilities should not be used as sediment control facilities and all drainage should be directed away from bioretention facilities after initial rough grading. Flow can be directed away from the facility with temporary diversion swales or other approved protection.

Construction of bioretention facilities should not begin until all contributing drainage areas are stabilized according to erosion and sediment control BMPs and to the satisfaction of the engineer.

If the design includes curb and gutter, the curb cuts and inlets should be blocked until Bioretention Soil Mix and mulch have been placed and planting completed (when possible), and dispersion pads are in place.

Verification

If using the default bioretention soil media, pre-placement laboratory analysis for saturated hydraulic conductivity of the bioretention soil media is not required. Verification of the mineral aggregate gradation, compliance with the compost specifications, and the mix ratio must be provided.

If using a custom bioretention soil media, verification of compliance with the minimum design criteria cited above for such custom mixes must be provided. This will require laboratory testing of the material that will be used in the installation. Testing shall be performed by a Seal of Testing Assurance, AASHTO, ASTM or other standards organization accredited laboratory with current and maintained certification. Samples for testing must be supplied from the BSM that will be placed in the bioretention areas.

If testing infiltration rates is necessary for post-construction verification use the Pilot Infiltration Test (PIT) method or a double ring infiltrometer test (or other small-scale testing allowed by the local government with jurisdiction). If using the PIT method, do not excavate Bioretention Soil Mix (conduct test at level of finished Bioretention Soil Mix elevation), use a maximum of 6 inch ponding depth and conduct test before plants are installed.

Maintenance

Maintenance requirements for bioretention facilities are See the requirements set forth in Chapter 4.6 of this volume, and in Volume VI Stormwater Facilities y Maintenance.

BMP T7.40: Compost-amended Vegetated Filter Strips (CAVFS)

Description

The CAVFS is a variation of the basic vegetated filter strip that adds soil amendments to the roadside embankment (see Figure 5.10). The soil amendments improve infiltration characteristics, increase surface roughness, and improve plant sustainability. Once permanent vegetation is established, the advantages of the CAVFS are higher surface roughness; greater retention and infiltration capacity; improved removal of soluble cationic contaminants through sorption; improved overall vegetative health; and a reduction of invasive weeds. Compostamended systems have somewhat higher construction costs due to more expensive materials, but require less land area for runoff treatment, which can reduce overall costs.

Application

CAVFS can be used to meet basic runoff treatment and enhanced runoff treatment objectives. It has practical application in areas where there is space for roadside embankments that can be built to the CAVFS specifications.

Soil design criteria

The CAVFS design incorporates composted material into the native soils per the criteria in BMP T5.13 for turf areas. The compost shall not contain biosolids or manure.

Soil/Compost Mix

- Presumptive approach: Place and rototill 1.75 inches of composted material into 6.25 inches
 of soil (a total amended depth of about 9.5 inches), for a settled depth of 8 inches. Water or
 roll to compact soil to 85% maximum. Plant grass.
- Custom approach: Place and rototill the calculated amount of composted material into a depth of soil needed to achieve 8 inches of settled soil at 5% organic content. Water or roll to compact soil to 85% maximum. Plant grass. The amount of compost or other soil amendments used varies by soil type and organic matter content. If there is a good possibility that site conditions may already contain a relatively high organic content, then it may be possible to modify the pre-approved rate described above and still be able to achieve the 5% organic content target.
- The final soil mix (including compost and soil) should have an initial saturated hydraulic conductivity less than 12 inches per hour, and a minimum long-term hydraulic conductivity of 1.0 inch/hour per ASTM Designation D 2434 (Standard Test Method for Permeability of Granular Soils) at 85% compaction per ASTM Designation D 1557 (Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort. Infiltration rate and hydraulic conductivity are assumed to be approximately the same in a uniform mix soil. Note: Long term saturated hydraulic conductivity is determined by applying the appropriate infiltration correction factors as explained under "Determining Bioretention soil mix infiltration rate" under BMP T7.30.

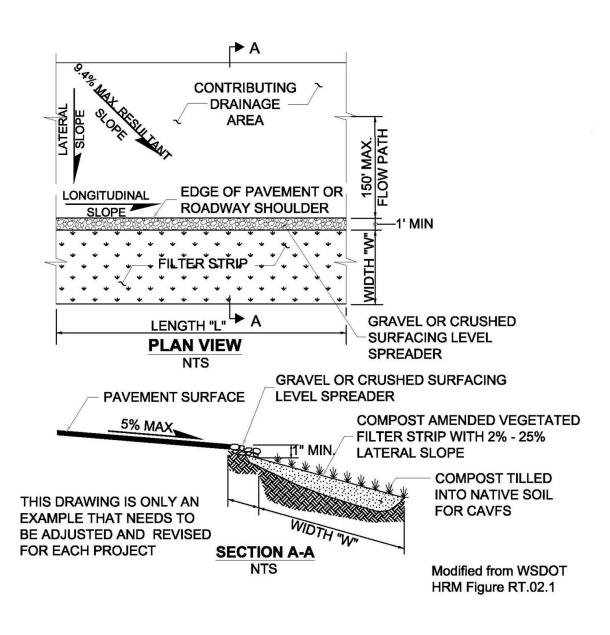


Figure 5.10 – Example of a Compost Amended Vegetated Filter Strip (CAVFS)

- The final soil mixture should have a minimum organic content of 5% by dry weight per ASTM Designation D 2974 (Standard Test Method for Moisture, Ash and Organic Matter of Peat and Other Organic Soils) (Tackett, 2004).
- Achieving the above recommendations will depend on the specific soil and compost characteristics. In general, the recommendation can be achieved with 60% to 65% loamy sand mixed with 25% to 30% compost or 30% sandy loam, 30% coarse sand, and 30% compost.
- The final soil mixture should be tested prior to installation for fertility, micronutrient analysis, and organic material content.
- Clay content for the final soil mix should be less than 5%.
- Compost must not contain biosolids, manure, street or highway sweepings, or catch basin solids.
- The pH for the soil mix should be between 5.5 and 7.0. If the pH falls outside the acceptable range, it may be modified with lime to increase the pH or iron sulfate plus sulfur to lower the pH. The lime or iron sulfate must be mixed uniformly into the soil prior to use in LID areas (Low-Impact Development Center, 2004).
- The soil mix should be uniform and free of stones, stumps, roots, or other similar material larger than 2 inches.
- When placing topsoil, it is important that the first lift of topsoil is mixed into the top of the existing soil. This allows the roots to penetrate the underlying soil easier and helps prevent the formation of a slip plane between the two soil layers.

Soil Component

The texture for the soil component of the LID BMP soil mix should be loamy sand (USDA Soil Textural Classification).

Compost Component

Follow the specifications for compost in BMP T7.30 – Bioretention

Hydrologic modeling creditsRunoff model representation

The CAVFS will have an "Element" in the approved continuous runoff models that must be used for determining the amount of water that is treated by the CAVFS. To fully meet treatment requirements, Ninety one 91 percent of the influent runoff file must pass through the soil profile of the CAVFS. Water that flows over the surface is not considered treated. Approved hydrologic models should be able to report the estimated amount of water passing through the soil profile.

Protection of CAVFS during construction

See information related to bioretention facilities.

Maintenance

For maintenance of CAVFS, use the relevant maintenance requirements for bioretention systems as set forth in Chapter 4.6 of this volume. See the requirements set forth in Chapter 4.6 of this volume, and applicable sections of bioretention system maintenance methods and standards in Volume VI Stormwater Facility Maintenance.

Chapter 8 Granular Media Filters

8.1 Purpose

Granular media filters can provide basic treatment or other treatment in accordance with the requirements of Volume I, Chapter 4.

8.2 Description

A typical granular media filter system consists of a pretreatment system, flow spreader(s), a filtration bed of one or more types of granular media, and underdrain piping, and if needed, a liner. An impermeable liner under the facility may also be needed if the filtered runoff requires additional treatment to remove soluble ground water pollutants, or in cases where additional ground water protection was mandated.

The granular media filters described in this chapter include various configurations of sand filter, and a system called a Media Filter Drain. Bioretention systems, which are also a type of granular medium filter, are described in Chapter 7 of this volume.

8.3 [RESERVED]

8.4 Applications and Limitations

See Snohomish County EDDS Chapter 5-13.

Figures 5.11 through 5.16 and Snohomish County EDDS Standard Drawings 5-300A and 5-300B provide information on various sand filter configurations.

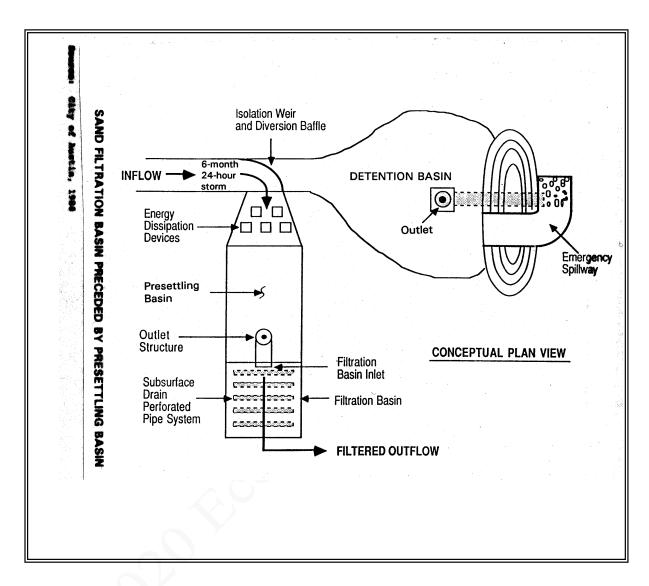


Figure 5.11 – Sand Filtration Basin Preceded by Presettling Basin

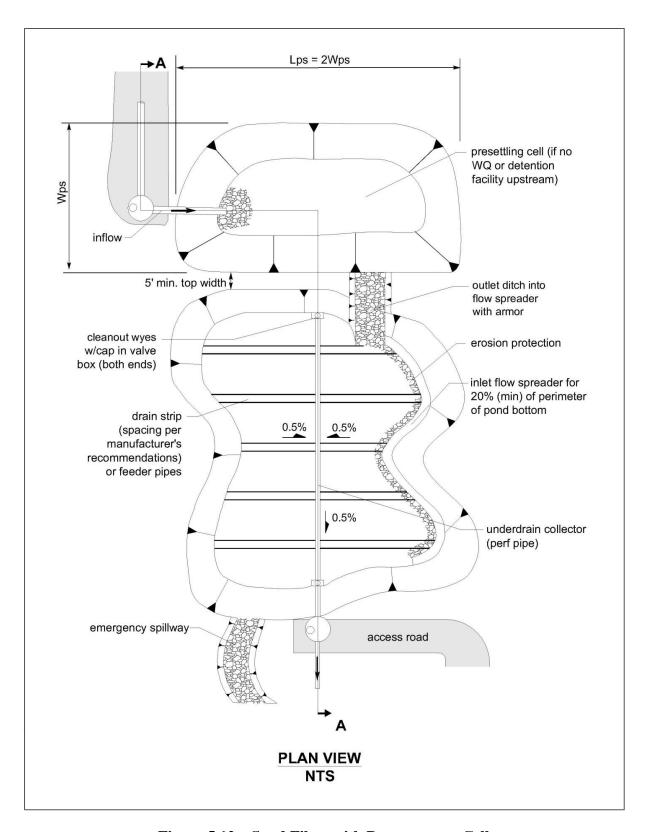


Figure 5.12 – Sand Filter with Pretreatment Cell

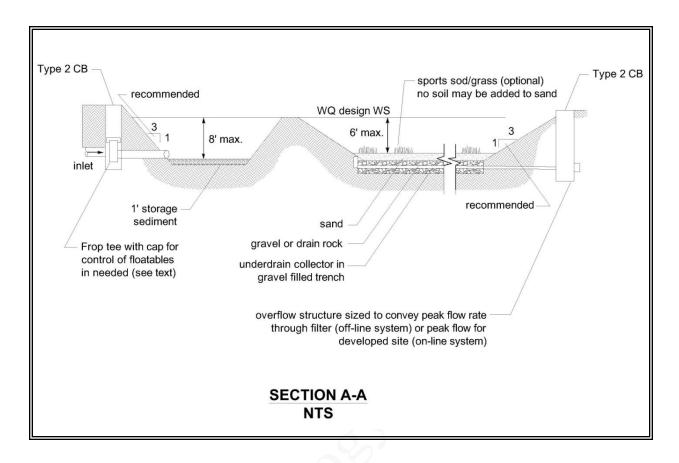


Figure 5.13 – Sand Filter with Pretreatment Cell (Section)

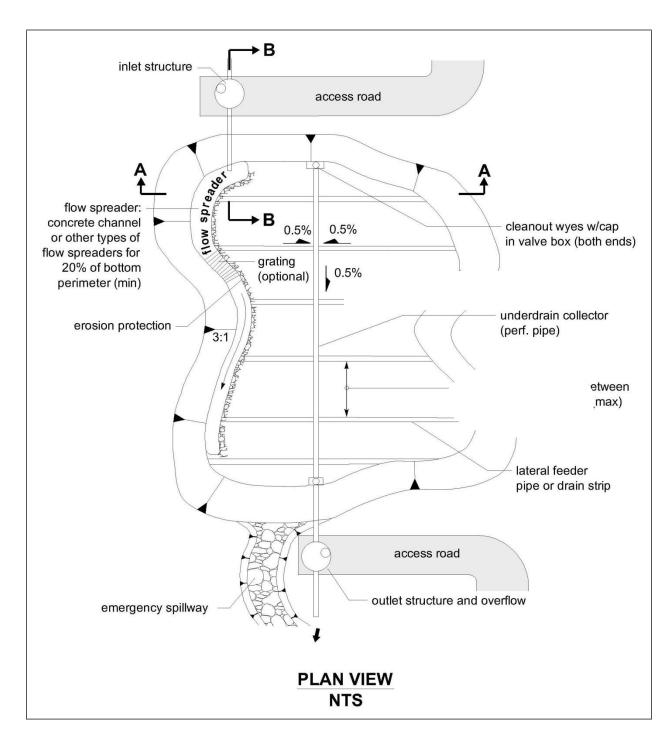


Figure 5.14 – Sand Filter with Level Spreader

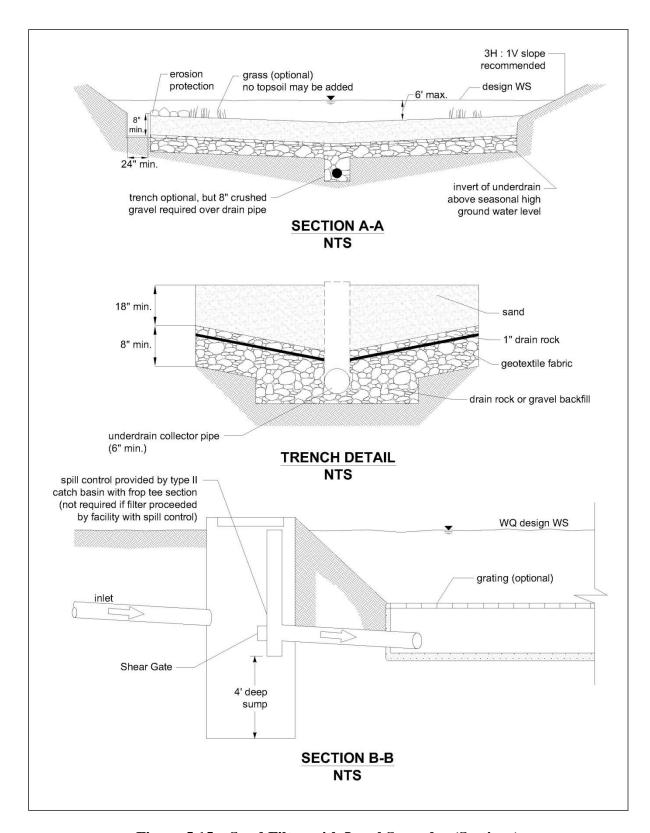


Figure 5.15 – Sand Filter with Level Spreader (Sections)

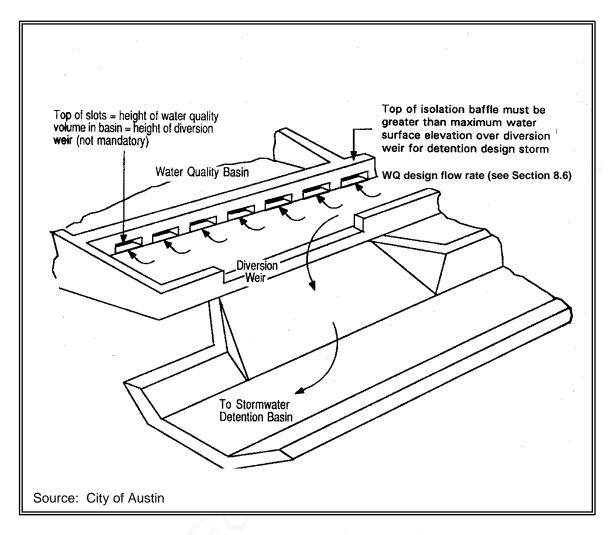


Figure 5.16 – Example Isolation/Diversion Structure

8.5 BMPs for Sand Filtration

BMP T8.10 - Basic sand filter basin

Description

A sand filter basin filters stormwater through a constructed sand bed with an underdrain system.

Applications and limitations

Use a sand filter basin to capture and treat the Water Quality Design Storm volume, which is 91% of the total runoff volume as predicted by Western Washington Hydrology Model (WWHM)water quality design volume as defined in Chapter 4.1.1 of this volume. Only 9% of the total runoff volume should bypass or overflow from the sand filter facility.

Site suitability

Consider the following site characteristics when siting a sand filtration system:

- Space availability, including a presettling basin
- Sufficient hydraulic head, at least 4 feet from inlet to outlet
- Adequate Operation and Maintenance capability including accessibility for O & M
- Sufficient pretreatment of oil, debris and solids in the tributary runoff

Design criteria

Pretreatment

Pretreatment is required in accordance with Chapter 6 of this volume.

Hydraulics

If the drainage area maintains a base flow between storm events, bypass the base flow around the filter to keep the sand from remaining saturated for extended periods.

Assume a design filtration rate of 1 inch per hour. Though the sand specified below will initially infiltrate at a much higher rate, that rate will slow as the filter accumulates sediment. When the filtration rate falls to 1 inch per hour, removal of sediment is necessary to maintain rates above the rate assumed for sizing purposes.

System configuration

On-line design

- Do NOT place upstream of a detention facility, in order to prevent exposure of the sand filter surface to high flow rates that could cause loss of media and previously removed pollutants.
- Size on-line sand filters placed downstream of a detention facility using <u>WWHM or</u> an approved <u>equivalent</u> continuous runoff <u>hydrologic</u> model to filter the water quality runoff volume.

• Include an overflow in the design. The overflow height should be at the maximum hydraulic head of the pond above the sand bed. On-line filters shall have overflows (primary, secondary, and emergency) in accordance with the design criteria for detention ponds in Volume III, Chapter 3.

Off-line design

- Off-line sand filters placed upstream of a detention facility must have a flow splitter designed to send all flows at or below the 15 minute water quality flow rate, as predicted by WWHM, to the sand filter.
- Size the facility to filter all the runoff sent to it (no overflows from the treatment facility should occur). Note that WWHM allows bypass flows and filtered runoff to be directed to the downstream detention facility.
- Off-line sand filters placed downstream of a detention facility must have a flow splitter designed to send all flows at or below the 2-year flow frequency from the detention pond, as predicted by WWHM, to the treatment facility. The treatment facility must be sized to filter all the runoff sent to it (no overflows from the treatment facility should occur).
- For off-line filters, design the underdrain structure to pass the 2-year peak inflow rate, as determined using 15 minute time steps in an approved continuous runoff hydrologic model.

Inlet and outlet design

- Inlet and outlet design shall be in accordance with the requirements of Snohomish County EDDS Chapter 5-13E.
- If the sand filter is curved or an irregular shape, provide a flow spreader for a minimum of 20 percent of the filter perimeter.
- If the length-to-width ration of the filter is 2:1 or greater, locate a flow spreader on the longer side of the filter and for a minimum length of 20 percent of the facility perimeter.
- Provide erosion protection along the first foot of the sand bed adjacent to the flow spreader.
 Methods for this include geotextile weighted with sand bags at 15-foot intervals and quarry spalls.

Underdrains

- Underdrains shall be designed in accordance with the requirements of Snohomish County EDDS Chapter 5-13D.
- Types of acceptable underdrains are:
 - A central collector pipe with lateral feeder pipes in an 8-inch gravel backfill or drain rock bed.
 - o A central collector pipe with a geotextile drain strip in an 8-inch gravel backfill or drain rock bed
 - Longitudinal pipes in an 8-inch gravel backfill or drain rock with a collector pipe at the outlet end.

Sand specification

The sand shall be 18 inches minimum in depth and must consist of a medium sand meeting the size gradation (by weight) specified below. The contractor must obtain a grain size analysis from the supplier to certify that the sand meets the No. 100 and No. 200 sieve requirements. Note: Standard backfill for sand drains, WSDOT Std. Spec. 9-03.13, does not meet this specification.

Sieve	% Passing
4	<u>95-100</u>
8	<u>70-100</u>
<u>16</u>	<u>40-90</u>
<u>30</u>	<u>25-75</u>
<u>50</u>	<u>2-25</u>
100	<u><4</u>
200	<2

<u>Sieve</u>	% Passing
4	95 - 100
8	70 - 100
16	40 90
30	25 75
50	2-25
100	<u>4</u>
200	\rightarrow
200	

Liners

Liners shall be provided in accordance with the requirement of Snohomish County EDDS Chapter 5-13.

Access

Access shall be designed in accordance with the requirement of Snohomish County EDDS Chapter 5-13I.

Setback and separation distances

Setback and separation distances shall be in accordance with SCC 30.63A.710 and Snohomish County EDDS Chapter 5-13.

Construction criteria

No runoff should enter the sand filter prior to completion of construction and approval of site stabilization by the responsible inspector. Construction runoff may be routed to a pretreatment sedimentation facility, but discharge from sedimentation facilities should by-pass downstream sand filters. Careful level placement of the sand is necessary to avoid formation of voids within the sand that could lead to short-circuiting, (particularly around penetrations for underdrain cleanouts) and to prevent damage to the underlying geomembranes and underdrain system. Overcompaction should be avoided to ensure adequate filtration capacity. Sand is best placed with a low ground pressure bulldozer (4 psig or less). After the sand layer is placed water settling is recommended. Flood the sand with 10-15 gallons of water per cubic foot of sand.

Maintenance

Maintenance requirements for sand filters are set forth in Chapter 4.6 of this volume. See the requirements and standards set forth in Chapter 4.6 of this volume and in Volume VI Stormwater Facility Maintenance.

BMP T8.11 Large Sand Filter Basin

Description

A Large Sand Filter Basin is virtually identical to a Basic Sand Filter Basin except that it is sized to provide a higher level of treatment. A Basic Sand Filter Basin is approved as a Basic Treatment BMP, and a Large Sand Filter Basin is approved as an Enhanced Treatment BMP.

Applications and limitations

The Large Sand Filter is generally subject to the same Applications and Limitations as BMP T8.10 Basic Sand Filter Basin. The difference is that the Large Sand Filter Basin uses a higher Water Quality Design Stormwater quality design volume: 95% of the runoff volume of the period modeled in the WWHMan approved continuous runoff hydrologic model. Only 5% of the total runoff volume as modeled by WWHM would bypass or overflow from the sand filter facility.

Locate off-line sand filters either upstream or downstream of detention facilities. Only locate online sand filters downstream of detention to prevent exposure of the sand filter surface to high flow rates that could cause loss of media and previously removed pollutants.

Site suitability

See BMP T8.10 Basic Sand Filter Basin.

Design criteria

Design Volume

The facility should be sized to capture the Water Quality Design Volume, which is 95% of the runoff volume for the Large Sand Filter Basin (as opposed the 91% for the Basic Sand Filter Basin).

Overflow and Underdrains

The design flows for the overflow and underdrains must be increased from BMP T8.10 Basic Sand Filter Basin to this BMP for the Large Sand Filter Basin.

The Basic Sand Filter Basin that uses the 91% runoff volume as the Water Quality Design Volume, a 2-year return interval peak flow from WWHM or equivalent approved continuous model. The corresponding Overflow and Underdrain Design flow is the 2 Year Storm.

Thus, the Overflow and Underdrain design flow can be calculated by increasing the 2 year return interval peak flow by the ratio of the 95% runoff volume (water quality design volume for this BMP, Large Sand Filter) and the 91% runoff volume (water quality design volume for BMP T8.10 Basic Sand Filter Basin). In equation form:

Design Flow rate for Large Sand Filter Overflow or Under drain = (95% runoff Volume)/(91% Runoff Volume) * 2 year return interval peak flow.

For all other design and maintenance criteria, refer to BMP T8.10 Basic Sand Filter Basin.

BMP T8.20 Sand Filter Vault

Description

A sand filter vault is similar to an open sand filter except that the sand layer and underdrains are installed below grade in a vault. It consists of presettling and sand filtration cells. See Figures 5.17 and 5.18 for more details.

Applications and limitations

- Use where space limitations preclude above ground facilities
- Not suitable where high water table and heavy sediment loads are expected
- An elevation difference of 4 feet between inlet and outlet is needed.

Site suitability

See BMP T8.10 Basic Sand Filter Basin and Snohomish County EDDS Chapter 5-17.

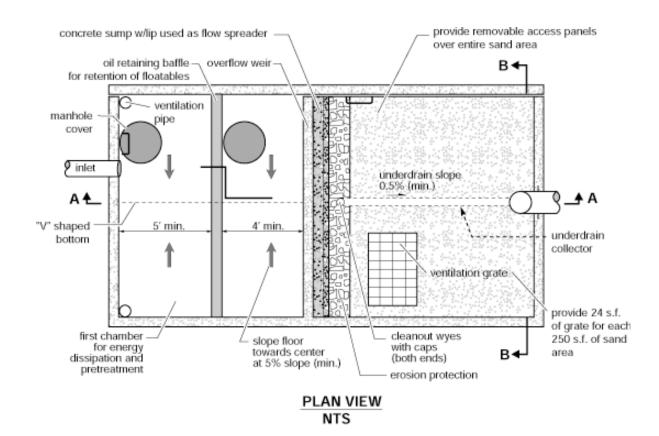
Design criteria

See BMP T8.10 Basic Sand Filter Basin and Snohomish County EDDS Chapter 5-17. Additional design criteria are set forth below.

- Vaults may be designed as off-line systems or on-line for small drainages. In an off-line system a diversion structure should be installed to divert the design flow rate into the sediment chamber and bypass the remaining flow to detention/retention (if necessary to meet Minimum Requirement #7), or to surface water.
- A geotextile fabric over the entire sand bed may be installed that is flexible, highly permeable, three-dimensional matrix, and adequately secured. This is useful in trapping trash and litter.

Access, setback and separation distances, construction criteria, and maintenance

See BMP T8.10 Basic Sand Filter Basin and Snohomish County EDDS Chapter 5-17.



5.17 – Sand Filter Vault

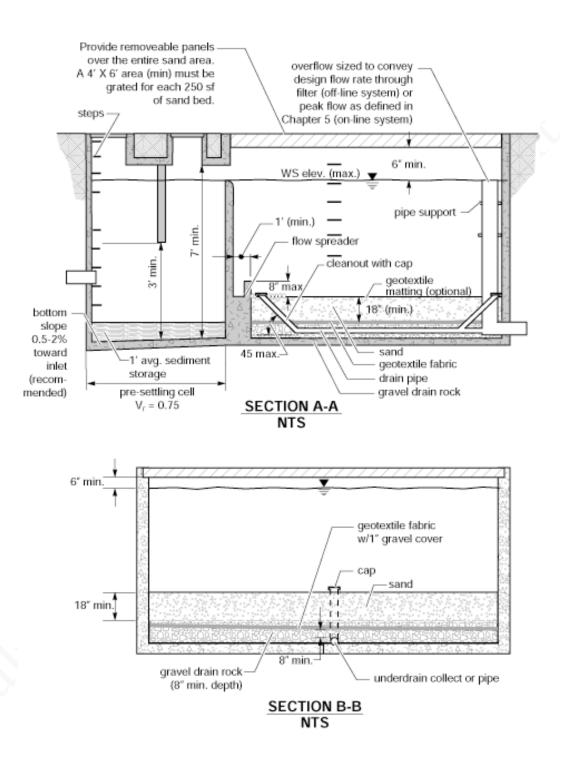


Figure 5.18 – Sand filter vault - sections

BMP T8.30 Linear Sand Filter

Description

Linear sand filters are typically long, shallow, two-celled, rectangular vaults. The first cell is designed for settling coarse particles, and the second cell contains the sand bed. Stormwater flows into the second cell via a weir section that also functions as a flow spreader (see Figure 5.19).

Applications and limitations

- Applicable in long narrow spaces such as the perimeter of a paved surface
- As a part of a treatment train as downstream of a filter strip, upstream of an infiltration system, or upstream of a wet pond or a biofilter for oil control.
- To treat small drainages (less than 2 acres of impervious area).
- To treat runoff from high-use sites for TSS and oil/grease removal, if applicable.

Design criteria

See BMP T8.10 – Basic sand filter basin for design criteria. Additional criteria are set forth below.

- The two cells should be divided by a divider wall that is level and extends between 6 and 12 inches above the sand bed.
- Stormwater may enter the sediment cell by sheet flow or a piped inlet.
- The width of the sand cell must be 1 foot minimum to 15 feet maximum.
- The sand filter bed must be a minimum of 12 inches deep and have an 8-inch layer of drain rock with perforated drainpipe beneath the sand layer.
- The drainpipe must be 6-inch diameter minimum and be wrapped in geotextile and sloped a minimum of 0.5 percent.
- Maximum sand bed ponding depth: 1-foot.
- Must be vented as for sand filter vaults
- Linear sand filters must conform to the materials and structural suitability criteria specified for wet vaults.
- Set sediment cell width as follows:

Filter width (inches)	12-24	24-48	48-72	>72
Sediment cell width	12	18	24	Width/3

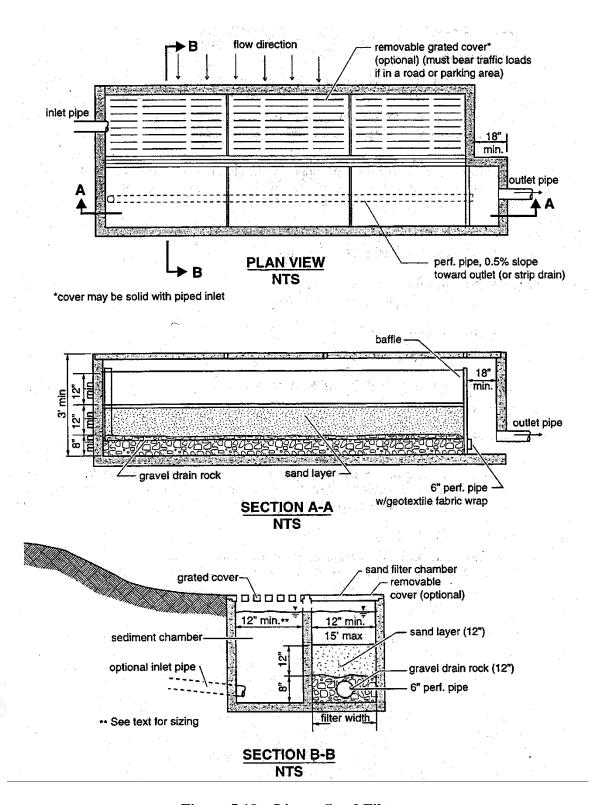


Figure 5.19 – Linear Sand Filter

BMP T8.40 Media Filter Drain (previously called Ecology Embankment)

Description

The media filter drain (MFD), previously referred to as the Ecology Embankment, is a linear flow-through stormwater runoff treatment device that can be sited along highway side slopes (conventional design) and medians (dual media filter drains), borrow ditches, or other linear depressions. Cut-slope applications may also be considered. The media filter drain can be used where available right of way is limited, sheet flow from the highway surface is feasible, and lateral gradients are generally less than 25% (4H:1V). The media filter drain has a General Use Level Designation (GULD) for basic, enhanced, and phosphorus treatment.

Media filter drains (MFDs) have four basic components: a gravel no-vegetation zone, a grass strip, the MFD mix bed, and a conveyance system for flows leaving the MFD mix. This conveyance system usually consists of a gravel-filled underdrain trench or a layer of crushed surfacing base course (CSBC). This layer of CSBC must be porous enough to allow treated flows to freely drain away from the MFD mix.

Typical MFD configurations are shown in Figures 5.20, 5.21, and 5.22.

The media filter drain removes suspended solids, phosphorus, and metals from highway runoff through physical straining, ion exchange, carbonate precipitation, and biofiltration.

Stormwater runoff is conveyed to the media filter drain via sheet flow over a vegetation-free gravel zone to ensure sheet dispersion and provide some pollutant trapping. Next, a grass strip, which may be amended with composted material, is incorporated into the top of the fill slope to provide pretreatment, further enhancing filtration and extending the life of the system. The runoff is then filtered through a bed of porous, alkalinity-generating granular medium—the media filter drain mix. Media filter drain mix is a fill material composed of crushed rock (sized by screening), dolomite, gypsum, and perlite. The dolomite and gypsum additives serve to buffer acidic pH conditions and exchange light metals for heavy metals. Perlite is incorporated to improve moisture retention, which is critical for the formation of biomass epilithic biofilm to assist in the removal of solids, metals, and nutrients. Treated water drains from the media filter drain mix bed into the conveyance system below the media filter drain mix. Geotextile lines the underside of the media filter drain mix bed and the conveyance system.

The underdrain trench is an option for hydraulic conveyance of treated stormwater to a desired location, such as a downstream flow control facility or stormwater outfall. The trench's perforated underdrain pipe is a protective measure to ensure free flow through the media filter drain mix and to prevent prolonged ponding. It may be possible to omit the underdrain pipe if it can be demonstrated that the pipe is not necessary to maintain free flow through the media filter drain mix and underdrain trench.

It is critical to note that water should sheet flow across the media filter drain. Channelized flows or ditch flows running down the middle of the dual media filter drain (continuous off-site inflow) should be minimized.

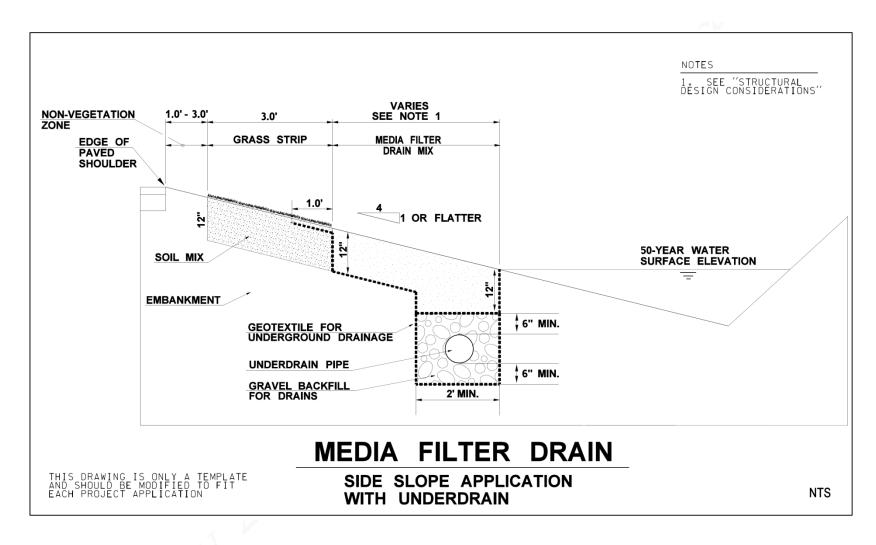
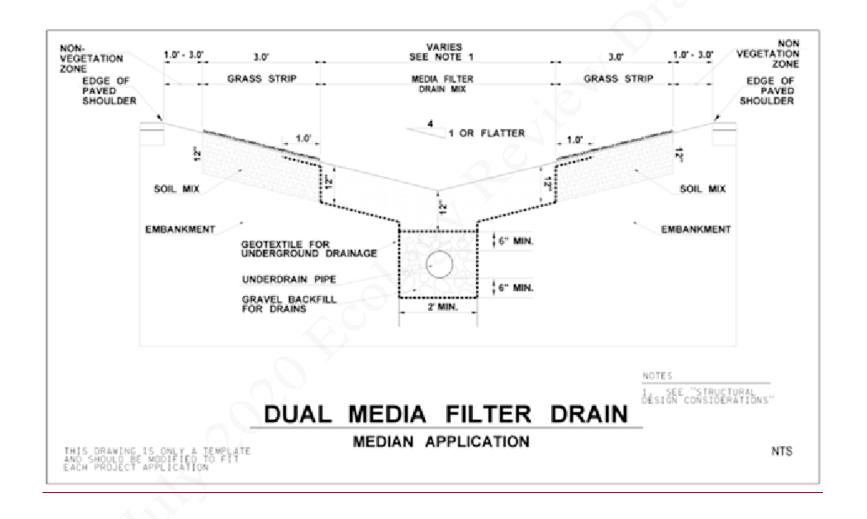


Figure 5.20 - Media Filter Drain: Sideslope Application with Underdrain



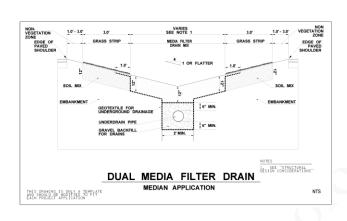


Figure 5.21 - Dual Media Filter Drain: Median Application

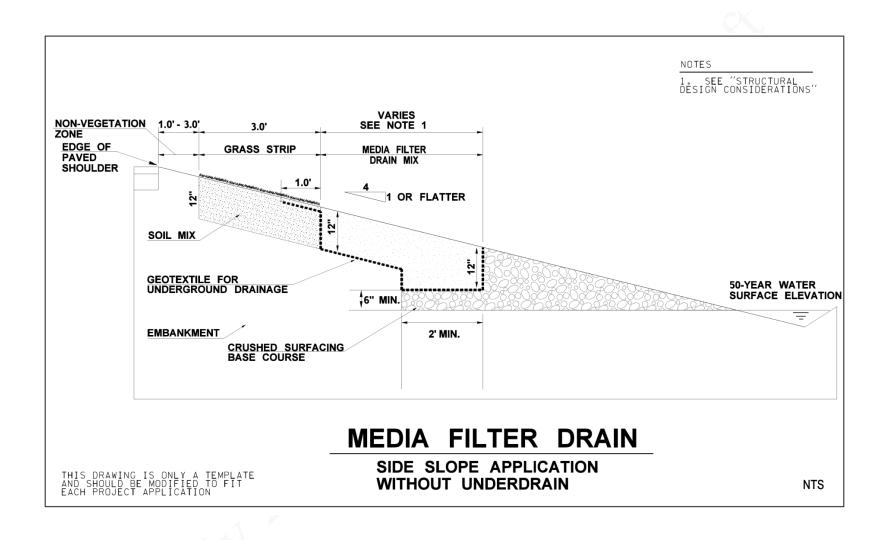


Figure 5.22 - Media Filter Drain: Side Slope Application without Underdrain

Applications and limitations

In many instances, conventional runoff treatment is not feasible due to right-of-way constraints (such as adjoining wetlands and geotechnical considerations). The media filter drain and the dual media filter drain designs are runoff treatment options that can be sited in most right-of-way confined situations. In many cases, a media filter drain or a dual media filter drain can be sited without the acquisition of additional right-of-way needed for conventional stormwater facilities or capital-intensive expenditures for underground wet vaults.

Applications

Media Filter Drains

The media filter drain can achieve basic, phosphorus, and enhanced water quality treatment.

Since maintaining sheet flow across the media filter drain is required for its proper function, the ideal locations for media filter drains in highway settings are highway side slopes or other long, linear grades with lateral side slopes less than 4H:1V and longitudinal slopes no steeper than 5%. As side slopes approach 3H:1V, without design modifications, sloughing may become a problem due to friction limitations between the separation geotextile and underlying soils. The longest flow path from the contributing area delivering sheet flow to the media filter drain should not exceed 150 feet.

If there is sufficient roadway embankment width, the designer should consider placing the grass strip and media mix downslope when feasible.

Dual Media Filter Drain for Highway Medians

The dual media filter drain is fundamentally the same as the side-slope version. It differs in siting and is more constrained with regard to drainage options. Prime locations for dual media filter drains in a highway setting are medians, roadside drainage or borrow ditches, or other linear depressions. It is especially critical for water to sheet flow across the dual media filter drain. Channelized flows or ditch flows running down the middle of the dual media filter drain (continuous off-site inflow) should be minimized.

Limitations

Media Filter Drains

- Avoid construction on longitudinal slopes steeper than 5% and on lateral slopes greater than 3H:1V slopes, and preferably use less than 4H:1V slopes. In areas where lateral slopes exceed 4H:1V, it may be possible to construct terraces to create 4H:1V slopes or to otherwise stabilize up to 3H:1V slopes.
- Do not construct in wetlands and wetland buffers. In many cases, a media filter drain (due to its small lateral footprint) can fit within the highway fill slopes adjacent to a wetland buffer. In those situations where the highway fill prism is located adjacent to wetlands, an interception trench/underdrain will need to be incorporated as a design element in the media filter drain.

- Mean high water table levels at the project site need to be determined to ensure the media filter drain mix bed and the underdrain (if needed) will not become saturated by shallow ground water.
- In areas where slope stability may be problematic, consult a geotechnical engineer.
- Site-specific piezometer data may be needed in areas of suspected seasonal high ground water inundations. The hydraulic and runoff treatment performance of the dual media filter drain may be compromised due to backwater effects and lack of sufficient hydraulic gradient.
- In areas where there is a narrow roadway shoulder that does not allow enough room for a vehicle to fully stop or park, consider placing the MFD farther down the embankment slope. This will reduce the amount of rutting in the MFD and decrease overall maintenance repairs.

Design criteria

Design flow

The basic design concept behind the media filter drain and dual media filter drain is to fully filter all runoff through the media filter drain mix. Therefore, the infiltration capacity of the medium and drainage below needs to match or exceed the hydraulic loading rate.

System components

No-Vegetation Zone

The no-vegetation zone is a shallow gravel zone located directly adjacent to the highway pavement. The no-vegetation zone is a crucial element in a properly functioning media filter drain or other BMPs that use sheet flow to convey runoff from the highway surface to the BMP. The no-vegetation zone functions as a level spreader to promote sheet flow and a deposition area for coarse sediments. The no-vegetation zone should be between 1 foot and 3 feet wide. Depth will be a function of how the roadway section is built from subgrade to finish grade; the resultant cross section will typically be triangular to trapezoidal. Within these bounds, width varies depending on maintenance spraying practices.

Grass Strip

The width of the grass strip is dependent on the availability of space within the highway side slope. The baseline design criterion for the grass strip within the media filter drain is a 3-foot-minimum-width, but wider grass strips are recommended if the additional space is available. The designer may consider adding aggregate to the soil mix to help minimize rutting problems from errant vehicles. The soil mix should ensure grass growth for the design life of the media filter drain. Composted material used in the grass strip shall meet the specifications for compost used in Bioretention Soil Media (see BMP T7.30).

Media Filter Drain Mix Bed

The media filter drain mix is a mixture of crushed rock, dolomite, gypsum, and perlite. The crushed rock provides the support matrix of the medium; the dolomite and gypsum add alkalinity and ion exchange capacity to promote the precipitation and exchange of heavy metals; and the perlite improves moisture retention to promote the formation of biomass within the media filter

drain mix. The combination of physical filtering, precipitation, ion exchange, and biofiltration enhances the water treatment capacity of the mix. The media filter drain mix has an estimated initial filtration rate of 50 inches per hour and a long-term filtration rate of 28 inches per hour due to siltation. With an additional safety factor, the rate used to size the length of the media filter drain should be 10 inches per hour.

Conveyance System Below Media Filter Drain Mix

The gravel underdrain trench provides hydraulic conveyance when treated runoff needs to be conveyed to a desired location such as a downstream flow control facility or stormwater outfall.

In Group C and D soils, an underdrain pipe would help to ensure free flow of the treated runoff through the media filter drain mix bed. In some Group A and B soils, an underdrain pipe may be unnecessary if most water percolates into subsoil from the underdrain trench. The need for underdrain pipe should be evaluated in all cases. The underdrain trench should be a minimum of 2 feet wide for either the conventional or dual media filter drain.

The gravel underdrain trench may be eliminated if there is evidence to support that flows can be conveyed laterally to an adjacent ditch or onto a fill slope that is properly vegetated to protect against erosion. The media filter drain mix should be kept free draining up to the 50-year storm event water surface elevation represented in the downstream ditch.

Sizing Criteria

Width

The width of the media filter drain mix bed is determined by the amount of contributing pavement routed to the embankment. The surface area of the media filter drain mix bed needs to be sufficiently large to fully infiltrate the runoff treatment design flow rate using the long-term filtration rate of the media filter drain mix. For design purposes, a 50% safety factor is incorporated into the long-term media filter drain mix filtration rate to accommodate variations in slope, resulting in a design filtration rate of 10 inches per hour. The media filter drain mix bed should have a bottom width of at least 2 feet in contact with the conveyance system below the media filter drain mix.

Length

In general, the length of a media filter drain or dual media filter drain is the same as the contributing pavement. Any length is acceptable as long as the surface area media filter drain mix bed is sufficient to fully infiltrate the runoff treatment design flow rate.

Cross Section

In profile, the surface of the media filter drain should preferably have a lateral slope less than 4H:1V (<25%). On steeper terrain, it may be possible to construct terraces to create a 4H:1V slope, or other engineering may be employed if approved by Ecology, to ensure slope stability up to 3H:1V. If sloughing is a concern on steeper slopes, consideration should be given to incorporating permeable soil reinforcements, such as geotextiles, open-graded/ permeable pavements, or commercially available ring and grid reinforcement structures, as top layer components to the media filter drain mix bed. Consultation with a geotechnical engineer is required.

Inflow

Runoff is conveyed to a media filter drain using sheet flow from the pavement area. The longitudinal pavement slope contributing flow to a media filter drain should be less than 5%.

Although there is no lateral pavement slope restriction for flows going to a media filter drain, the designer should ensure flows remain as sheet flow.

Media Filter Drain Mix Bed Sizing Procedure

The media filter drain mix should be a minimum of 12 inches deep, including the section on top of the underdrain trench.

For runoff treatment, sizing the media filter drain mix bed is based on the requirement that the runoff treatment water quality design flow rate from the pavement area, *QHighway*, cannot exceed the long-term infiltration capacity of the media filter drain, *QInfiltration*:

Highway Infiltration
$$Q \leq Q$$
 Infiltration

For western Washington, *Quighway* is the flow rate at or below which 91% of the runoff volume for the developed TDA will be treated, based on a 15-minute time step- and can be determined using and approved continuous runoff model.

The long-term infiltration capacity of the media filter drain is based on the following equation:

$$Q$$
 Infiltration = $(LTIR * L * W) / (C*SF)$

in which:

LTIR = Long-term infiltration rate of the media filter drain mix (use 10 inches per hour for design) (in/hr)
 L = Length of media filter drain (parallel to roadway) (ft)
 W = Width of the media filter drain mix bed (ft)
 C = Conversion factor of 43200 ((in/hr)/(ft/sec))
 SF = Safety Factor (equal to 1.0, unless unusually heavy sediment loading is expected)

Assuming that the length of the media filter drain is the same as the length of the contributing pavement, solve for the width of the media filter drain:

$$W \ge \underline{Q_{Highway} *C*SF}$$
$$LTIR*L$$

Western Washington project applications of this design procedure have shown that, in almost every case, the calculated width of the media filter drain does not exceed 1.0 foot. Therefore, Table 5.5 was developed to simplify the design steps and should be used to establish an appropriate width.

Table 5.5 Design Widths for Media Filter Drains		
Pavement width that contributes runoff to the media filter drain	Minimum media filter drain width*	
≤ 20 feet	2 feet	
≥ 20 and ≤ 35 feet	3 feet	
> 35 feet	4 feet	

^{*} Width does not include required 1-3 foot gravel vegetation-free zone or the 3-foot filter strip width

<u>Underdrain Design</u>

Underdrain pipe can provide a protective measure to ensure free flow through the media filter drain (MFD) mix and is sized similar to storm drains. For MFD underdrain sizing, an additional step is required to determine the flow rate that can reach the underdrain pipe. This is done by comparing the contributing basin flow rate to the infiltration flow rate through the media filter mix and then using the smaller of the two to size the underdrain. The analysis described below considers the flow rate per foot of MFD, which allows you the flexibility of incrementally increasing the underdrain diameter where long lengths of underdrain are required. When underdrain pipe connects to a storm drain system, place the invert of the underdrain pipe above the 25-year water surface elevation in the storm drain to prevent backflow into the underdrain system.

The following describes the procedure for sizing underdrains installed in combination with media filter drains.

Calculate the flow rate per foot from the contributing basin to the media filter drain. The
design storm event used to determine the flow rate should be relevant to the purpose of the
underdrain. For example, if the MFD installation is in western Washington and the
underdrain will be used to convey treated runoff to a detention BMP, size the underdrain for
the 50-year storm event (see Snohomish County EDDS Chapter 5 for conveyance system
requirements.

$$\frac{Q_{highway}}{ft} = \frac{Q_{highway}}{L_{MFD}}$$

where:

 $\frac{Q_{highway}}{ft} = \text{contributing flow rate per foot (cfs/ft)}$

 L_{MFD} = length of MFD contributing runoff to the underdrain (ft)

2. Calculate the MFD flow rate of runoff per foot given an infiltration rate of 10 in/hr through the media filter drain mix.

$$Q_{\frac{MFD}{ft}} = \frac{f \times W \times 1ft}{ft} \times \frac{1ft}{12in} \times \frac{1hr}{3600 \text{ sec}}$$

where:

3. Size the underdrain pipe to convey the runoff that can reach the underdrain trench. This is taken to be the smaller of the contributing basin flow rate or the flow rate through the MFD mix layer.

$$Q_{\underline{UD}} = smaller \left\{ Q_{\underline{highway}} \text{ or } Q_{\underline{MFD}} \right\}$$

where:

$$Q_{\frac{UD}{ft}}$$
 = underdrain design flow rate per foot (cfs/ft)

4. Determine the underdrain design flow rate using the length of the MFD and a factor of safety of 1.2.

$$Q_{UD} = 1.2 \times Q_{\frac{UD}{ft}} \times W \times L_{MFD}$$

where:

5. Given the underdrain design flow rate, determine the underdrain diameter. Round pipe diameters to the nearest standard pipe size and have a minimum diameter of 6 inches. For diameters that exceed 12 inches, contact the Washington State Department of Ecology for further design information.

$$D = 16 \left(\frac{(Q_{UD} \times n)}{s^{0.5}} \right)^{3/8}$$

where:

D =underdrain pipe diameter (inches)

n = Manning's coefficient

s = slope of pipe (ft/ft)

Materials

Media Filter Drain Mix

The media filter drain mix used in the construction of media filter drains consists of the amendments listed in Table 5.6. Mixing and transportation must occur in a manner that ensures the materials are thoroughly mixed prior to placement and that separation does not occur during transportation or construction operations.

These materials should be used in accordance with the APWA/WSDOT Standard Specifications:

- Gravel Backfill for Drains, 9-03.12(4)
- Underdrain Pipe, 7-01.3(2)
- Construction Geotextile for Underground Drainage, 9-33.1

Crushed Surfacing Base Course (CSBC)

If the design is configured to allow the media filter drain to drain laterally into a ditch, the crushed surfacing base course below the media filter drain should conform to Section 9-03.9(3) of the *Standard Specifications*.

Berms, Baffles, and Slopes

See *Geometry, Components* and *Sizing Criteria, Cross Section* under Structural Design Considerations above.

Table 5.6 Media filter drain mix

Amendment	Quantity
Mineral aggregate: Aggregate for Media Filter Drain Mix Aggregate for Media filter Drain Mix shall be manufactured from ledge rock, talus, or gravel in accordance with Section 3-01 of the Standard Specifications for Road, Bridge, and Municipal Construction (2002), which meets the following test requirements for quality. The use of recycled material is not permitted.:	3 cubic yards
Los Angeles Wear, 500 Revolutions 35% max. Degradation Factor 30 min.	
Aggregate for the Media Filter Drain Mix shall conform to the following requirements for grading and quality:	
Sieve Size Percent Passing (by weight) 1/2" square 100 3/8" square 90-100 U.S. No. 4 30-56 U.S. No. 10 0-10 U.S. No. 200 0-1.5	
% fracture, by weight, min. 75	
Static stripping test Pass	
retained on the U.S. No. 10. Aggregate for the Media Filter Drain shall be substantially free from adherent coatings. The presence of a thin, firmly adhering film of weathered rock shall not be considered as coating unless it exists on more than 50% of the surface area of any size between successive laboratory sieves.	
Perlite:	1 cubic yard
☐ Horticultural grade, free of any toxic materials) ☐ 0-30% passing US No. 18 Sieve ☐ 0-10% passing US No. 30 Sieve	per 3 cubic yards of mineral aggregate
Dolomite: CaMg(CO3)2 (calcium magnesium carbonate) ☐ Agricultural grade, free of any toxic materials) ☐ 100% passing US No. 8 Sieve	10 pounds per cubic yard of perlite
□ 0% passing US No. 16 Sieve	

Site design elements

Landscaping

Landscaping for the grass strip is the same as for biofiltration swales unless otherwise specified in the special provisions for the project's construction documents.

Construction

Use guideposts to delineate the media filter drain. If the media filter drain is in a critical aquifer recharge area for drinking water supplies, signage prohibiting the use of pesticides must be provided.

Maintenance

See the requirements and standards set forth in Chapter 4.6 of this volume and in Volume VI Stormwater Facility Maintenance. Maintenance will consist of routine roadside management. While herbicides must not be applied directly over the media filter drain, it may be necessary to periodically control noxious weeds with herbicides in areas around the media filter drain as part of a roadside management program. The use of pesticides may be prohibited if the media filter drain is in a critical aquifer recharge area for drinking water supplies. The designer should check with the local area water purveyor or local health department. Areas of the media filter drain that show signs of physical damage will be replaced by local maintenance staff in consultation with region hydraulics/water quality staff.

Do not allow vehicles or traffic on the MFD to minimize rutting and maintenance repairs

Chapter 9 Biofiltration Treatment Facilities

Biofilters are vegetated treatment systems (typically grass) that remove pollutants by means of sedimentation, filtration, soil sorption, and/or plant uptake. They are typically configured as swales or flat filter strips. This chapter addresses four Best Management Practices (BMPs) that are classified as biofiltration treatment facilities:

- BMP T9.10 Basic biofiltration swale
- BMP T9.20 Wet biofiltration swale
- BMP T9.30 Continuous inflow biofiltration swale
- BMP T9.40 Basic filter strip

9.1 Purpose

Biofiltration facilities, used by themselves, provide basic treatment. They can be used in combination with other treatment facilities in systems that provide additional treatment, in accordance with the requirements of Volume I, Chapter 4.

9.2 Applications

A biofilter can be used as a basic treatment BMP for contaminated stormwater runoff from roadways, driveways, parking lots, and highly impervious ultra-urban areas or as the first stage of a treatment train. In cases where hydrocarbons, high TSS, or debris would be present in the runoff, such as high-use sites, a pretreatment system for those components would be necessary. Off-line location is preferred to avoid flattening vegetation and the erosive effects of high flows. Biofilters should be considered in retrofit situations where appropriate.

9.3 Site Suitability

The following factors must be considered for determining site suitability:

- Target pollutants are amenable to biofilter treatment
- Accessibility for Operation and Maintenance
- Suitable growth environment; (soil, etc.) for the vegetation
- Adequate siting for a pre-treatment facility if high petroleum hydrocarbon levels (oil/grease) or high TSS loads could impair treatment capacity or efficiency
- If the biofilter can be impacted by snowmelts and ice, refer to Caraco and Claytor for additional design criteria (USEPA, 1997).

9.4 Best Management Practices

BMP T9.10 Basic Biofiltration Swale

Description

Biofiltration swales are typically shaped as a trapezoid or a parabola as shown in Figure 5.23.

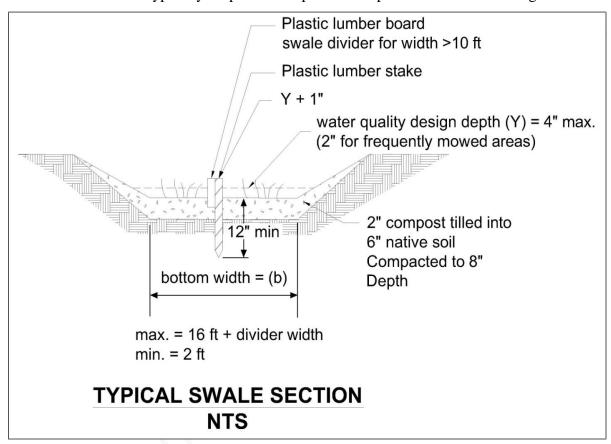


Figure 5.23 – Typical Swale Section

Limitations

Data suggest that the performance of biofiltration swales is highly variable from storm to storm. It is therefore recommended that treatment methods providing more consistent performance, such as sand filters and wet ponds, be considered first. Swales downstream of devices of equal or greater effectiveness can convey runoff but should not be expected to offer a treatment benefit.

Design Criteria

Design criteria are specified in Table 5.7. A 9-minute hydraulic residence time is used at a
multiple of the peak 15 minute water quality design flow rate (Q) as defined in Chapter 4 of
this volume.

- Check the hydraulic capacity/stability for inflows greater than design flows. Bypass high flows, or control release rates into the biofilter, if necessary.
- Install level spreaders (see Volume II, BMP C206) at the head and every 50 feet in swales of
 ≥4 feet width. Include sediment cleanouts (weir, settling basin, or equivalent) at the head of
 the biofilter as needed.
- Use energy dissipaters (riprap) for increased downslopes.

Guidance for Bypassing Off-line Facilities:

Most biofiltration swales are currently designed to be on-line facilities. However, an off-line design is possible. Swales designed in an off-line mode should not engage a bypass until the flow rate exceeds a value determined by multiplying Q, the off-line water quality design flow rate predicted by the WWHMas determined by an approved continuous runoff hydrologic model, by the ratio determined in Figure 5.27. This modified design flow rate is an estimate of the design flow rate determined by using SBUH procedures. Ecology's intent is to maintain recent biofiltration sizing recommendations (9 minutes detention at the peak design flow rate estimated by SBUH for a 6-month, 24-hour storm with a Type 1A rainfall distribution) until more definitive information is collected concerning bioswale performance. The only advantage of designing a swale to be off-line is that the stability check, which may make the swale larger, is not necessary.

Sizing Procedure for Biofiltration Swales

This guide provides biofilter swale design procedures in full detail, along with examples.

Preliminary Steps (P)

- **P-1** Determine the Water Quality design flow rate (Q) in 15 minute time steps using the WWHM. Use the correct flow rate, off-line or on-line, for your design situation.
- P-2 Establish the longitudinal slope of the proposed biofilter.
- **P-3** Select a vegetation cover suitable for the site. Refer to Tables 5.7 and 5.8 to select vegetation.

Design Calculations for Biofiltration Swale

There are a number of ways of applying the design procedure introduced by Chow (Chow, 1959). These variations depend on the order in which steps are performed, what constants are established at the beginning of the process and which ones are calculated, and what values are assigned to the variables selected initially.

The procedure recommended here is an adaptation appropriate for biofiltration applications of the type being installed in the Puget Sound region. This procedure reverses Chow's order, designing first for capacity and then for stability. The capacity analysis emphasizes the promotion of biofiltration, rather than transporting flow with the greatest possible hydraulic efficiency. Therefore, it is based on criteria that promote sedimentation, filtration, and other pollutant removal mechanisms. Because these criteria include a lower maximum velocity than

permitted for stability, the biofilter dimensions usually do not have to be modified after a stability check.

Design Steps (D):

D-1. Select the type of vegetation, and design depth of flow (based on frequency of mowing and type of vegetation).

D-2. Select a value of Manning's n (See Table 5.7)

	BMP T 9.10-Biofiltration	\$ C
Design parameter	swale	BMP T 9.40-Filter strip
Longitudinal Slope	$0.015 - 0.025^{1}$	0.01 - 0.15
	1 ft / sec (@ K multiplied by	
	the WQ design flow rate;	
Maximum velocity	for stability, 3 ft/sec max.	0.5 ft / sec
	2"- if mowed frequently; 4" if	
Maximum water depth ²	mowed infrequently	1-inch max.
		0.35 (0.45 if compost-amende
	$(0.2 - 0.3)^3 (0.24 \text{ if mowed})$	and mowed to maintain grass
Manning coefficient (22)	infrequently)	height ≤ 4")
Bed width (bottom)	$(2 - 10 \text{ ft})^4$	
Freeboard height	0.5 ft	
Minimum hydraulic	1	
residence time at Water	9 minutes (18 minutes for	
Quality Design Flow	continuous inflow)	
Rate	(See Volume I, Appendix B)	9 minutes
		Sufficient to achieve hydrauli
Minimum length	100 ft	residence time in the filter stri
	3 H : 1 V	Inlet edge ≥ 1 " lower than
Maximum sideslope	4H:1V preferred	contributing paved area
Max. tributary drainage		
flowpath		150 feet
		0.05 (steeper than 0.05 need
Max. longitudinal slope		upslope flow spreading and ene
of contributing area		dissipation)
Max. lateral slope of		
contributing area		0.02 (at the edge of the strip inl

- 1. For swales, if the slope is less than 1.5% install an underdrain using a perforated pipe, or equivalent. Amend the soil if necessary to allow effective percolation of water to the underdrain. Install the low-flow drain 6" deep in the soil. Slopes greater than 2.5% need steps made of concrete blocks or poured in place retaining walls with rock filled sumps at the downstream side. Underdrains can be made of 6 inch Schedule 40 PVC perforated pipe with 6" of drain gravel on the pipe. The gravel and pipe must be enclosed by geotextile fabric. (See Figures 5.24 and 5.25)
- 2 Below the design water depth install an erosion control blanket, at least 4" of topsoil, and the selected biofiltration mix. Above the water line use a straw mulch or sod.
- 3. This range of Manning's n can be used in the equation; b = Qn/1.49y(1.67) s(0.5) Zy with wider bottom width b, and lower depth, y, at the same flow. This provides the designer with the option of varying the bottom width of the swale depending on space limitations. Designing at the higher n within this range at the same flow decreases the hydraulic design depth, thus placing the pollutants in closer contact with the vegetation and the soil.

4.	For swale widths up to 16 feet the cross-section can be divided with a berm (concrete, plastic, compacted earthfill) using a flow spreader at the inlet (Figure 5.26)

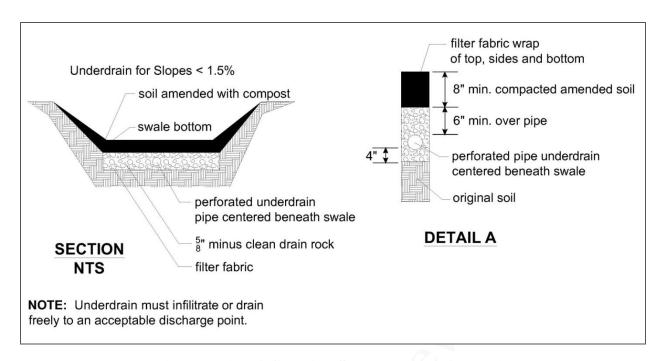


Figure 5.24 – Biofiltration Swale Underdrain Detail

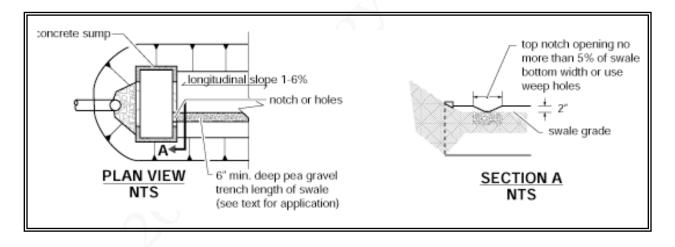


Figure 5.25 – Biofiltration Swale Low-Flow Drain Detail

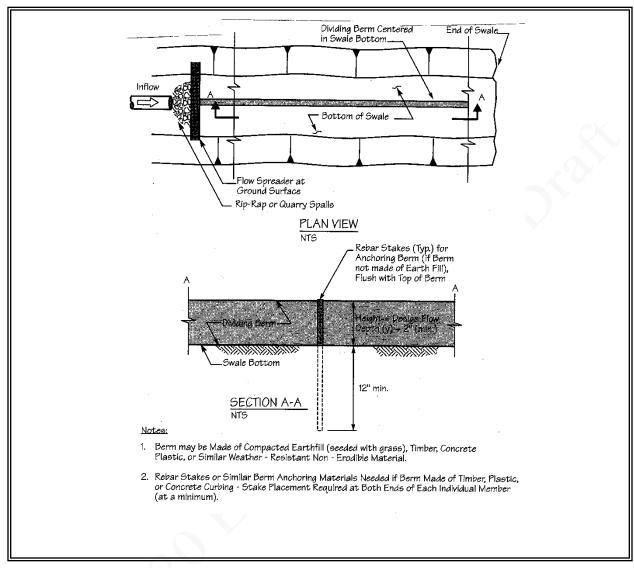


Figure 5.26 – Swale Dividing Berm

- **D-3**. Select swale shape-typically trapezoidal or parabolic.
- **D-4**. Use Manning's equation and first approximations relating hydraulic radius and dimensions for the selected swale shape to obtain a working value of a biofilter width dimension:

$$Q = \frac{1.49AR^{0.67}s^{0.5}}{n}$$
 (equation 1)
$$A_{rectangle} = Ty$$
 (equation 2)

$$R_{\text{rectangle}} = \frac{Ty}{T + 2y}$$
 (equation 3)

w\here:

Q = Water Quality Design flow rate in 15-minute time steps based on WWHM, (ft³/s, cfs)

n = Manning's n (dimensionless)

s = Longitudinal slope as a ratio of vertical rise/horizontal run (dimensionless)

 $A = Cross-sectional area (ft^2)$

R = Hydraulic radius (ft)

T = top width of trapezoid or width of a rectangle (ft)

y = depth of flow (ft)

b = bottom width of trapezoid (ft)

If equations 2 and 3 are substituted into equation 1 and solved for T, complex equations result that are difficult to solve manually. However, approximate solutions can be found by recognizing that T>>y and $Z^2>>1$, and that certain terms are nearly negligible. The approximation solutions for rectangular and trapezoidal shapes are:

$$R_{rectangle} \approx y$$
, $R_{trapezoid} \approx y$, $R_{parabolic} \approx 0.67y$, $R_v \approx 0.5y$

Substitute $R_{trapezoid}$ and $A_{trapezoid} = by+Zy^2$ into Equation 1, and solve for the bottom width b (trapezoidal swale):

$$b \approx \frac{2.5Qn}{1.49y^{1.67}s^{0.5}} - Zy$$

For a trapezoid, select a side slope Z of at least 3. Compute b and then top width T, where T = b + 2yZ. (Note: Adjustment factor of 2.5 accounts for the differential between Water Quality design flow rate and the SBUH design flow. This equation is used to estimate an initial cross-sectional area. It does not affect the overall biofiltration swale size.)

If b for a swale is greater than 10 ft, either investigate how Q can be reduced, divide the flow by installing a low berm, or arbitrarily set b = 10 ft and continue with the analysis. For other swale shapes refer to Fig. 5.27.

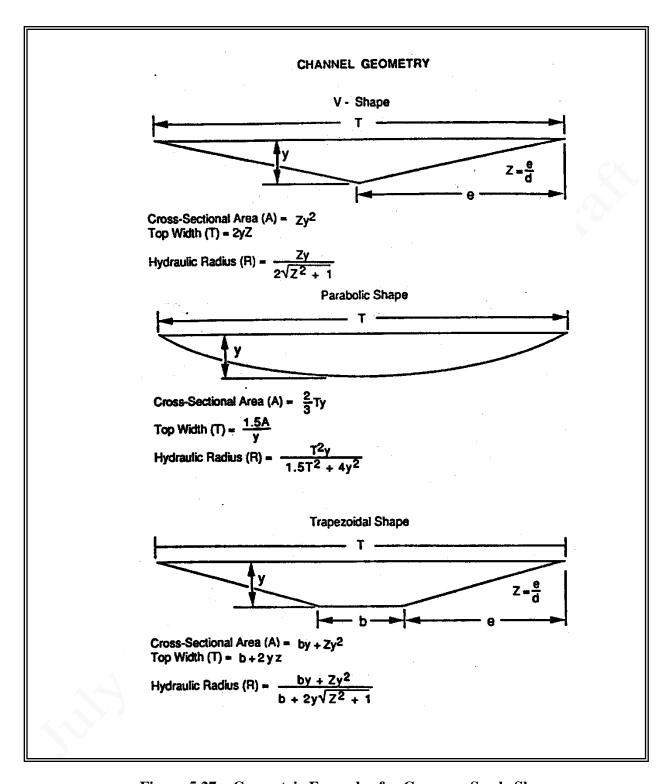


Figure 5.27 – Geometric Formulas for Common Swale Shapes

D-5. Compute A:

$$A_{rectangle} = Ty \text{ or } A_{trapazoid} = by + Zy^2$$

$$A_{\text{filter strip}} = Ty$$

D-6. Compute the flow velocity at design flow rate:

$$V = \kappa \frac{Q}{A}$$

K = A ratio of the peak volumetric flow rate using a 10-minute time step predicted by SBUH to the water quality design flow rate <u>estimated using the WWHM</u>. The value of K is determined from Figure 5.28 for on-line facilities, or Figure 5.29 for off-line facilities.

If V >1.0 ft/sec (or V>0.5 ft/sec for a filter strip), repeat steps D-1 to D-6 until the condition is met. A velocity greater than 1.0 ft/sec was found to flatten grasses, thus reducing filtration. A velocity lower than this maximum value will allow a 9-minute hydraulic residence time criterion in a shorter biofilter. If the value of V suggests that a longer biofilter will be needed than space permits, investigate how Q can be reduced (e.g., use of low impact development BMP's), or increase y and/or T (up to the allowable maximum values) and repeat the analysis.

D-7. Compute the swale length (L, ft)

L = Vt (60 sec/min)

Where: t = hydraulic residence time (min)

Use t = 9 minutes for this calculation (use t = 18 minutes for a continuous inflow biofiltration swale). If a biofilter length is greater than the space permits, follow the advice in step D-6.

If a length less than 100 feet results from this analysis, increase it to 100 feet, the minimum allowed. In this case, it may be possible to save some space in width and still meet all criteria. This possibility can be checked by computing V in the 100 ft biofilter for t=9 minutes, recalculating A (if V<1.0 ft/sec) and recalculating T.

D-8. If there is still not sufficient space for the biofilter, Snohomish County and the project proponent should consider the following solutions (listed in order of preference):

- 1. 1)—Divide the site drainage to flow to multiple biofilters.
- 2. 2)—Use infiltration to provide lower discharge rates to the biofilter (only if the Site Suitability Criteria in Chapter 3, Volume III are met).
- 3. 3)—Increase vegetation height and design depth of flow (note: the design must ensure that vegetation remains standing during design flow).
- 4. 4)—Reduce the developed surface area to gain space for biofiltration.
- 5. 5)—Increase the longitudinal slope.
- 6. 6)—Increase the side slopes.
- 7. —Nest the biofilter within or around another BMP.

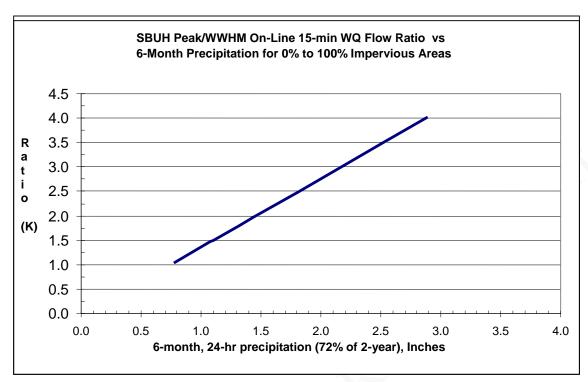
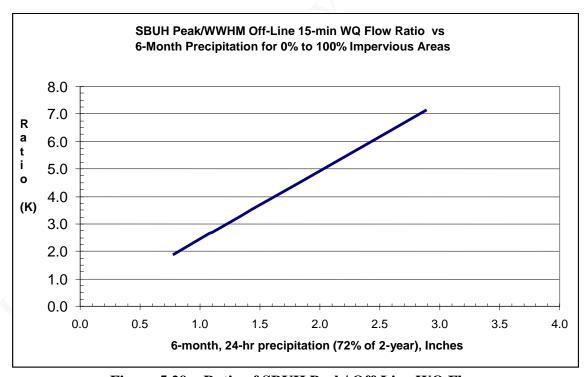


Figure 5.28 - Ratio of SBUH Peak/On-Line WQ Flow



Figure~5.29-Ratio~of~SBUH~Peak/~Off-Line~WQ~Flow

Check for Stability (Minimizing Erosion)

The stability check must be performed for the combination of highest expected flow and least vegetation coverage and height. A check is not required for biofiltration swales that are located "off-line" from the primary conveyance/detention system, Maintain the same units as in the biofiltration capacity analysis.

- **SC-1**. Perform the stability check for the 100-year, return frequency flow using 15-minute time steps using derived using an approved continuous runoff <u>hydrologic</u> model. Until WWHM peak flow rates in 15 minute time steps are available the designer can use the WWHM 100 yr. hourly peak flows times an adjustment factor of 1.6 to approximate peak flows in 15 minute time steps.
- **SC-2**. Estimate the vegetation coverage ("good" or "fair") and height on the first occasion that the biofilter will receive flow, or whenever the coverage and height will be least. Avoid flow introduction during the vegetation establishment period by timing planting or bypassing.
- **SC-3.** Estimate the degree of retardance from Table 5.8. When uncertain, be conservative by selecting a relatively low degree.

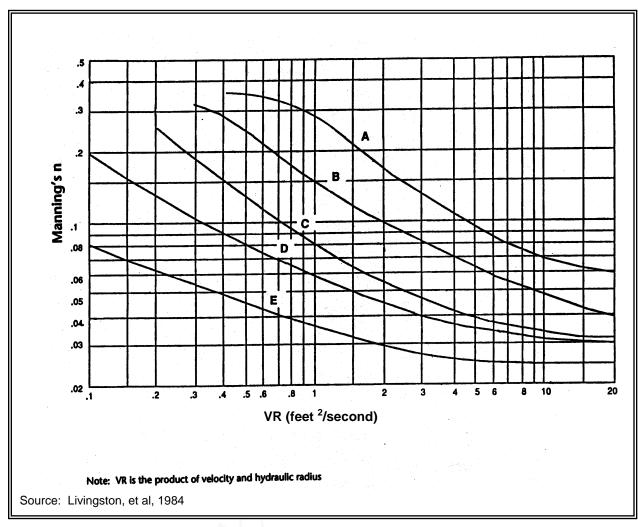
The maximum permissible velocity for erosion prevention (Vmax) is 3 feet per second.

Stability Check Steps (SC)

Table 5.8 – Guide for Selecting Degree of Retardance (a)		
	Average Grass	4
Coverage	Height (inches)	Degree of Retardance
Good	<2	E. Very Low
	2-6	D. Low
	6-10	C. Moderate
	11-24	B. High
	>30	A. Very High
Fair	<2	E. Very Low
	2-6	D. Low
	6-10	D. Low
	11-24	C. Moderate
	>30	B. High

See Chow (1959). In addition, Chow recommended selection of retardance C for a grass-legume mixture 6-8 inches high and D for a mixture 4-5 inches high. No retardance recommendations have appeared for emergent wetland species. Therefore, judgment must be used. Since these species generally grow less densely than grasses, using a "fair" coverage would be a reasonable approach.

- **SC-4.** Select a trial Manning's n for the high flow condition. The minimum value for poor vegetation cover and low height (possibly, knocked from the vertical by high flow) is 0.033. A good initial choice under these conditions is 0.04.
- **SC-5.** Refer to Figure 5.30 to obtain a first approximation for VR of 3 feet/second.



 $\begin{tabular}{ll} Figure~5.30-Relationship~of~Manning's~n~with~VR~for~Various~Degrees~of~Flow~Retardance \end{tabular}$

- **SC-6.** Compute hydraulic radius, R, from VR in Figure 5.19 and a Vmax
- **SC-7**. Use Manning's equation to solve for the actual VR.
- **SC-8.** Compare the actual VR from step SC-7 and first approximation from step SC-5. If they do not agree within 5 percent, repeat steps SC-4 to SC-8 until acceptable agreement is reached. If n<0.033 is needed to get agreement, set n=0.033, repeat step SC-7, and then proceed to step SC-9.
- **SC-9.** Compute the actual V for the final design conditions:

Check to be sure $V < V_{\text{max of 3 feet/second.}}$

- **SC-10**. Compute the required swale cross-sectional area, A, for stability:
- **SC-11**. Compare the A, computed in step SC-10 of the stability analysis, with the A from the biofiltration capacity analysis (step D-5).

If less area is required for stability than is provided for capacity, the capacity design is acceptable. If not, use A from step SC-10 of the stability analysis and recalculate channel dimensions.

- **SC-12**. Calculate the depth of flow at the stability check design flow rate condition for the final dimensions and use A from step SC-10.
- **SC-13.** Compare the depth from step SC-12 to the depth used in the biofiltration capacity design (Step D-1). Use the larger of the two and add 0.5 ft. of freeboard to obtain the total depth (y_t) of the swale. Calculate the top width for the full depth using the appropriate equation.
- **SC-14.** Recalculate the hydraulic radius: (use b from Step D-4 calculated previously for biofiltration capacity, or Step SC-11, as appropriate, and $y_t = \text{total depth from Step SC-13}$)
- **SC-15.** Make a final check for capacity based on the stability check design storm (this check will ensure that capacity is adequate if the largest expected event coincides with the greatest retardance). Use Equation 1, a Manning's n selected in step D-2, and the calculated channel dimensions, including freeboard, to compute the flow capacity of the channel under these conditions. Use R from step SC-14, above, and $A = b(y_t) + Z(y_t)^2$ using b from Step D-4, D-15, or SC-11 as appropriate.

If the flow capacity is less than the stability check design storm flow rate, increase the channel cross-sectional area as needed for this conveyance. Specify the new channel dimensions.

Completion Step (CO)

CO. Review all of the criteria and guidelines for biofilter planning, design, installation, and operation above and specify all of the appropriate features for the application.

Example of Design Calculations for Biofiltration Swales

Preliminary Steps

P-1. Assume that the WWHM based Water Quality Design Flow Rate in 15 minute time steps, Q, is 0.2 cfs. Assume an on-line facility.

P-2. Assume the slope (s) is 2 percent.

P-3. Assume the vegetation will be a grass-legume mixture and it will be infrequently mowed.

Design for Biofiltration Swale Capacity

D-1. Set winter grass height at 5" and the design flow depth (y) at 3 inches.

D-2. Use n = 0.20 to $-n_2 = 0.30$

D-3. Base the design on a trapezoidal shape, with a side slope Z = 3.

D-4a. Calculate the bottom width, b;

Where:

At
$$n_2$$
; $b_2 = 6.5$ feet

D-4b. Calculate the top width (T)

$$T = b + 2yZ = 4.0 + [2(0.25)(3)] = 5.5$$
 feet

D-5. Calculate the cross-sectional area (A)

$$A = by + Zy^2 = (4.0)(0.25) + (3)(0.25^2) = 1.19 \text{ ft}^2$$

D-6. Calculate the flow velocity (V)

$$V = K = \frac{Q}{A} = 0.17 \text{ ft / sec}$$

for K = 1. Actual K is determined per Figure 5.17

D-7. Calculate the Length (L)

$$L = Vt(60 \text{ sec/min})$$

= 0.17 (9)(60)

For t = 9 min, L = 92 ft. at n; expand to a minimum of 100 foot length per design criterion

At
$$n_2$$
; $L = -100$ ft.

Note: Where b is less than the maximum value, it may be possible to reduce L by increasing b. In this case, because L is determined by the requirement for a minimum length of 100 feet, it is not possible.

Check for Channel Stability

SC-1. Base the check on passing the 100-year, return frequency flow (15 minute time steps) through a swale with a mixture of Kentucky bluegrass and tall fescue on loose erodible soil. Until WWHM peak flow rates in 15 minute time steps are available the designer can use the WWHM 100-yr. hourly peak flows times an adjustment factor of 1.6 to approximate peak flows in 15 minute time steps. Assume that the adjusted peak Q is 1.92 cfs.

SC-2. Base the check on a grass height of 3 inches with "fair" coverage (lowest mowed height and least cover, assuming flow bypasses or does not occur during grass establishment).

SC-3. From Table 5.8, Degree of Retardance = D (low)

Set
$$V_{max} = 3$$
 ft/sec

SC-4. Select trial Manning's n = 0.04

SC-5. From Figure 5.19, $VR_{appx} = 3 \text{ ft}^2/\text{s}$

SC-6. Calculate R

$$R = \frac{VR_{appx}}{V_{max}} = 1.0 \text{ ft}$$

SC-7. Calculate VR_{actual}

$$VR_{actual} = \frac{1.49}{n} R^{1.67} s^{0.5} = 5.25 \text{ ft}^2 / \text{sec}$$

SC-8. VR_{actual} from step SC-7 > VR_{appx} from step SC-5 by > 5%.

Select new trial n = 0.0475

Figure 5.19: $VR_{appx} = 1.7 \text{ ft}^2/\text{s}$

R = 0.57 ft.

 $VR_{actual} = 1.73 \text{ ft}^2/\text{s}$ (within 5% of $VR_{appx} = 1.7$)

SC-9. Calculate V

$$V = \frac{VR_{actual}}{R} = \frac{1.73}{0.57} = 3 \text{ ft / sec}$$

$$V = 3 \text{ ft/sec} \le 3 \text{ ft/sec}, Vmax :: OK$$

SC-10. Calculate Stability Area

$$A_{Stability} = \frac{Q}{V} = \frac{1.92}{3} = 0.64 \text{ ft}$$

SC-11. Stability Check

$$A_{Stability} = 0.64 \text{ ft}^2 \text{ is less than } A_{Capacity} \text{ from step D-5 } (A_{Capacity} = 1.19 \text{ ft}^2).$$
 $\therefore OK$

If $A_{Stability} > A_{Capacity}$, it will be necessary to select new trial sizes for width and flow depth (based on space and other considerations), recalculate $A_{Capacity}$, and repeat steps SC-10 and SC-11.

SC-12. Calculate depth of flow at the stability design flow rate condition using the quadratic equation solution:

$$y = \frac{-b \pm \sqrt{b^2 - 4Z(-A)}}{2Z}$$

For
$$b = 4$$
, $y = 0.14$ ft (positive root)

SC-13. Use the greater value of y from SC-12 or that assumed in D-1. In this case, the greater depth is 0.25-foot, which was the basis for the biofiltration capacity design. Add 0.5 feet freeboard to that depth.

Total channel depth =
$$0.75$$
 ft
Top Width = $b + 2yZ$
= $4 + (2)(0.75)(3)$
= 8.5 ft

SC-14. Recalculate hydraulic radius and flow rate

For
$$b = 4$$
 ft, $y = 0.75$ ft
 $Z = 3$, $s = 0.02$, $n = 0.2$
 $A = by + Zy^2 = 4.68$ ft²
 $R = \{by + Zy^2\}/\{b + 2y(Z^2 + 1)^{0.5}\} = 0.53$ ft.

SC-15. Calculate Flow Capacity at Greatest Resistance

$$Q = \frac{1.49AR^{0.67}s^{0.5}}{n} = 3.2 \text{ cf}$$

$$Q = 3.2 \text{ cfs} > 1.92 \text{ cfs} :: OK$$
Completion Step

CO-1. Assume 100 feet of swale length is available.

The final channel dimensions are:

Bottom width,
$$b = 4$$
 feet
Channel depth= 0.75 feet
Top width $= b + 2yZ = 8.5$ feet

No check dams are needed for a 2% slope.

Soil Criteria

- The following top soil mix at least 8-inch deep:
 - Sandy loam ____60-90 %
 Clay ___-0-10 %
 Composted material; ____110-30 %
- Use compost amended soil where practicable. Composted material shall meet the specifications for compost used in the Bioretention Soil Media (see BMP T7.30). This excludes the use of biosolids and manure.
- Till to at least 8-inch depth
- For longitudinal slopes of < 2 percent use more sand to obtain more infiltration
- If groundwater contamination is a concern, seal the bed with clay or a geomembrane liner

Vegetation Criteria

- See Tables 5.13 and 5.14 for recommended plants.
- Select fine, turf-forming, water-resistant grasses where vegetative growth and moisture will be adequate for growth.
- Irrigate if moisture is insufficient during dry weather season.
- Use sod with low clay content and where needed to initiate adequate vegetative growth.
 Preferably sod should be laid to a minimum of one-foot vertical depth above the swale bottom.
- Consider sun/shade conditions for adequate vegetative growth and avoid prolonged shading of any portion not planted with shade tolerant vegetation.
- Stabilize soil areas upslope of the biofilter to prevent erosion

• Fertilizing a biofilter should be avoided if at all possible in any application where nutrient control is an objective. Test the soil for nitrogen, phosphorus, and potassium and consult with a landscape professional about the need for fertilizer in relation to soil nutrition and vegetation requirements. If use of a fertilizer cannot be avoided, use a slow-release fertilizer formulation in the least amount needed.

Recommended grasses (see Tables 5.9 and 5.10 below)

Table 5.9 – Grass Seed Mixes Suitable for Biofiltration Swale Treatment Areas			
	Mix 1		Mix 2
75-80 percent	tall or meadow fescue	60-70 percent	tall fescue
10-15 percent	seaside/colonial bentgrass	10-15 percent	seaside/colonial bentgrass
5-10 percent	Redtop	10-15 percent	meadow foxtail
		6-10 percent	alsike clover
		1-5 percent	marshfield big trefoil
		1-6 percent	Redtop

Note: All percentages are by weight.

<u> </u>	
	Table 5.10
- Groundcovers and Gras	sses Suitable for the Upper Side Slopes of
	Swale in Western Washington
Groundcovers	
kinnikinnick	Arctostaphylos uva-ursi
Epimedium	Epimedium grandiflorum
creeping forget-me-not	Omphalodes verna
	Euonymus lanceolata
yellow-root	Xanthorhiza simplissima
	Genista
white lawn clover	Trifolium repens
white sweet clover	Melilotus alba
	Rubus calycinoides
strawberry	Fragaria chiloensis
broadleaf lupine	Lupinus latifolius
Grasses (drought-tolerant, n	ninimum mowing)
dwarf tall fescues	Festuca spp. (e.g., Many Mustang, Silverado)
hard fescue	Festuca ovina duriuscula (e.g., Reliant,
	Aurora)
tufted fescue	Festuca amethystine
buffalo grass	Buchloe dactyloides
red fescue	Festuca rubra
tall fescue grass	Festuca arundinacea
blue oatgrass	Helictotrichon sempervirens

Construction Criteria

The biofiltration swale should not be put into operation until areas of exposed soil in the contributing drainage catchment have been sufficiently stabilized. Deposition of eroded soils

can impede the growth of grass in the swale and reduce swale treatment effectiveness. Thus, effective erosion and sediment control measures should remain in place until the swale vegetation is established (see Volume II for erosion and sediment control BMPs). Avoid compaction during construction. Grade biofilters to attain uniform longitudinal and lateral slopes.

Setback and separation distances

Setback and separation distances shall be in accordance with SCC 30.63A.710.

Maintenance

<u>See the Maintenance</u> requirements_for drainage facilities are set forth in Chapter 4.6 of this volume and in Volume VI Stormwater Facilityies Maintenance.

BMP T9.20 Wet Biofiltration Swale

Description

A wet biofiltration swale is a variation of a basic biofiltration swale for use where the longitudinal slope is slight, water tables are high, or continuous low base flow is likely to result in saturated soil conditions. Where saturation exceeds about 2 weeks, typical grasses will die. Thus, vegetation specifically adapted to saturated soil conditions is needed. Different vegetation in turn requires modification of several of the design parameters for the basic biofiltration swale.

Performance Objectives

Wet biofiltration swales provide basic treatment if used by themselves, and can be used in combination with other systems to provide additional treatment, in accordance with the requirements of Volume I, Chapter 4.

Applications/Limitations

Wet biofiltration swales are applied where a basic biofiltration swale is desired but not allowed or advisable because one or more of the following conditions exist:

- The swale is on till soils and is downstream of a detention pond providing flow control.
- Saturated soil conditions are likely because of seeps or base flows on the site.
- Longitudinal slopes are slight (generally less than 2 percent).

Design Criteria

Use the same design approach as for basic biofiltration swales except to add the following:

Adjust for extended wet season flow. If the swale will be downstream of a detention pond providing flow control, multiply the treatment area (bottom width times length) of the swale by 2, and readjust the swale length, if desired. Maintain a 5:1 length to width ratio.

<u>Intent</u>: An increase in the treatment area of swales following detention ponds is required because of the differences in vegetation established in a constant flow environment. Flows following detention are much more prolonged. These prolonged flows result in more stream-like conditions than are typical for other wet biofilter situations. Since vegetation growing in streams is often less dense, this increase in treatment area is needed to ensure that equivalent pollutant removal is achieved during extended flow events.

<u>Swale Geometry</u>: Same as specified for basic biofiltration swales except for the following modifications:

Criterion 1: The bottom width may be increased to 25 feet maximum, but a minimum length-to-width ratio of 5:1 must be provided. No longitudinal dividing berm is needed. Note: The minimum swale length is still 100 feet.

Criterion 2: If longitudinal slopes are greater than 2 percent, the wet swale must be stepped so that the slope within the stepped sections averages 2 percent. Steps may be made of concrete block or poured in place concrete retaining walls with rock filled sumps at the downstream side, log check dams, or short riprap sections. No underdrain or low-flow drain is required.

<u>High-Flow Bypass</u>: A high-flow bypass (i.e., an off-line design) is required for flows greater than the off-line water quality design flow that has been increased by the ratio indicated in Figure 5.27. The bypass is necessary to protect wetland vegetation from damage. Unlike grass, wetland vegetation will not quickly regain an upright attitude after being laid down by high flows. New growth, usually from the base of the plant, often taking several weeks, is required to regain its upright form. The bypass may be an open channel parallel to the wet biofiltration swale.

<u>Water Depth and Base Flow</u>: Same as for basic biofiltration swales except the design water depth shall be 4 inches for all wetland vegetation selections, and no underdrains or low-flow drains are required.

<u>Flow Velocity, Energy Dissipation, and Flow Spreading</u>: Same as for basic biofiltration swales except no flow spreader is needed.

<u>Access</u>: Same as for basic biofiltration swales except access is only required to the inflow and the outflow of the swale; access along the length of the swale is not required. Also, wheel strips may not be used for access in the swale.

<u>Intent</u>: An access road is not required along the length of a wet swale because of infrequent access needs. Frequent mowing or harvesting is not desirable. In addition, wetland plants are fairly resilient to sediment-induced changes in water depth, so the need for access should be infrequent.

Soil Amendment: Same as for basic biofiltration swales.

<u>Planting Requirements</u>: Same as for basic biofiltration swales except for the following modifications:

- 1. A list of acceptable plants and recommended spacing is shown in Table 5.11. In general, it is best to plant several species to increase the likelihood that at least some of the selected species will find growing conditions favorable.
- 2. A wetland seed mix may be applied by hydroseeding, but if coverage is poor, planting of rootstock or nursery stock is required. Poor coverage is considered to be more than 30 percent bare area through the upper 2/3 of the swale after four weeks.

Recommended Design Features:

Same as for basic biofiltration swales.

Construction Considerations:

Same as for basic biofiltration swales.

Setback and separation distances

Setback and separation distances shall be in accordance with SCC 30.63A.710.

Maintenance Considerations:

<u>See Maintenance</u> requirements <u>and standards</u> for drainage facilities are set forth in <u>Chapter 7.53.1407.54.080 SCC</u>, and Volume V, Chapter 4.6 of this <u>manual volume and Volume VI Stormwater Facility Maintenance</u>.

Table 5.11 – Recommended Plants for Wet Biofiltration Swale		
Common Name	Scientific Name	Spacing (on center)
Shortawn foxtail	Alopecurus aequalis	seed
Water foxtail	Alopecurus geniculatus	seed
Spike rush	Eleocharis spp.	4 inches
Slough sedge*	Carex obnupta	6 inches or seed
Sawbeak sedge	Carex stipata	6 inches
Sedge	Carex spp.	6 inches
Western mannagrass	Glyceria occidentalis	seed
Velvetgrass	Holcus mollis	seed
Slender rush	Juncus tenuis	6 inches
Watercress*	Rorippa nasturtium-aquaticum	12 inches
Water parsley*	Oenanthe sarmentosa	6 inches
Hardstem bulrush	Scirpus acutus	6 inches
Small-fruited bulrush	Scirpus microcarpus	12 inches

^{*} Good choices for swales with significant periods of flow, such as those downstream of a detention facility.

Note: Cattail (Typha latifolia) is not appropriate for most wet swales because of its very dense and clumping growth habit which prevents water from filtering through the clump.

BMP T9.30 Continuous Inflow Biofiltration Swale

Description

In situations where water enters a biofiltration swale continuously along the side slope rather than discretely at the head, a different design approach—the continuous inflow biofiltration swale—is needed. The basic swale design is modified by increasing swale length to achieve an equivalent average residence time.

Applications

A continuous inflow biofiltration swale is to be **used when inflows are not concentrated**, such as locations along the shoulder of a road without curbs. This design may also be **used where frequent, small point flows enter a swale**, such as through curb inlet ports spaced at intervals along a road, or from a parking lot with frequent curb cuts. In general, no inlet port should carry more than about 10 percent of the flow.

A continuous inflow swale is not appropriate for a situation in which significant lateral flows enter a swale at some point downstream from the head of the swale. In this situation, the swale width and length must be recalculated from the point of confluence to the discharge point in order to provide adequate treatment for the increased flows.

Design Criteria

Same as specified for **basic biofiltration swale** except for the following:

- The design flow for continuous inflow swales must include runoff from the pervious side slopes draining to the swale along the entire swale length. Therefore, they must be on-line facilities.
- If only a single design flow is used, the flow rate at the outlet should be used. The goal is to achieve an average residence time through the swale of 9 minutes as calculated using the online water quality design flow rate multiplied by the ratio, K, in Figure 5.28. Assuming an even distribution of inflow into the side of the swale double the hydraulic residence time to a minimum of 18 minutes.
- For continuous inflow biofiltration swales, interior side slopes above the WQ design treatment elevation shall be planted in grass. A typical lawn seed mix or the biofiltration seed mixes are acceptable. Landscape plants or groundcovers other than grass may not be used anywhere between the runoff inflow elevation and the bottom of the swale. **Intent:** The use of grass on interior side slopes reduces the chance of soil erosion and transfer of pollutants from landscape areas to the biofiltration treatment area.

Setback and separation distances

Setback and separation distances shall be in accordance with SCC 30.63A.710.

BMP T9.40 Basic Filter Strip

Description:

A basic filter strip is flat with no side slopes (Figure 5.31). Contaminated stormwater is distributed as sheet flow across the inlet width of a biofilter strip.

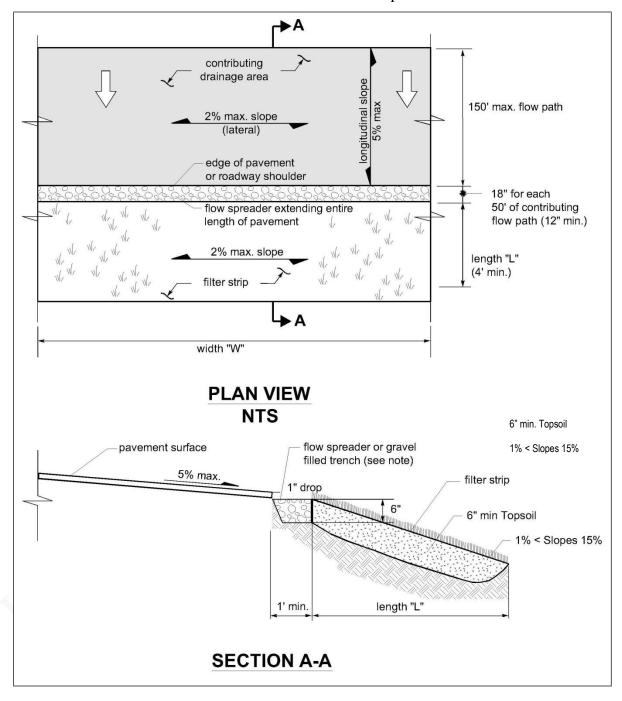


Figure 5.31 – Typical Filter Strip

Applications/Limitations:

The basic filter strip is typically used on-line and adjacent and parallel to a paved area such as parking lots, driveways, and roadways. Where a filter strip area is compost-amended to a minimum of 10% organic content in accordance with BMP T5.13; with hydroseeded grass maintained at 95% density and a 4-inch length by mowing and periodic re-seeding (possible landscaping with herbaceous shrubs), the filter strip serves as an Enhanced Treatment option.

Design Criteria for Filter strips:

- Use the Design Criteria specified in Table 5.7.
- Filter strips should only receive sheet flow.
- Use curb cuts \geq 12-inch wide and 1-inch above the filter strip inlet.

Calculate the design flow depth using Manning's equation as follows:

$$KQ = (1.49A R^{0.67} s^{0.5})/n$$

Substituting for AR:

$$KQ = (1.49Ty^{1.67} s^{0.5})/n$$

Where:

$$Ty = A_{rectangle, ft}^2$$

 $y \approx R_{rectangle}$, design depth of flow, ft. (1 inch maximum)

Q = peak Water Quality design flow rate based on WWHM, ft³/sec

____(See Appendix I-B, Volume I)

K =The ratio determined by using Figure 5. $\frac{1728}{}$

n = Manning's roughness coefficient

s = Longitudinal slope of filter strip parallel to direction of flow

T = Width of filter strip perpendicular to the direction of flow, ft.

A = Filter strip inlet cross-sectional flow area (rectangular), ft^2

R = hydraulic radius, ft.

Rearranging for y:

$$y = [KQn/1.49Ts^{0.5}]^{0.6}$$

y must not exceed 1 inch

Note: As in swale design an adjustment factor of K accounts for the differential between the WWHM-Water Quality design flow rate and the SBUH design flow

Calculate the design flow velocity V, ft./sec., through the filter strip:

$$V = KQ/Ty$$

V must not exceed 0.5 ft./sec

Calculate required length, ft., of the filter strip at the minimum hydraulic residence time, t, of 9 minutes:

$$L = tV = 540V$$

Chapter 10 Wetpool Facilities

10.1 —Purpose

This chapter presents the methods, criteria, and details for analysis and design of wetponds, wetvaults, and stormwater wetlands. These facilities have as a common element a permanent pool of water - the wetpool. Each of the wetpool facilities can be combined with a detention or flow control pond in a combined facility. Included are the following specific facility designs:

- BMP T10.10 Wetponds Basic and Large
- BMP T10.20 Wetvaults
- BMP T10.30 Stormwater Wetlands
- BMP T10.40 Combined Detention and Wetpool Facilities

10.2 ——Application

The wetpool facility designs described for the BMPs in this Chapter will achieve the performance objectives cited in Chapter 3 of this volume for specific treatment menus.

10.3 —Best Management Practices (BMPs) for Wetpool Facilities

The BMPs discussed below are currently recognized as effective treatment techniques using wetpool facilities. The specific BMPs that are selected should be coordinated with the Treatment Facility Menus discussed in Chapter 3.

BMP T10.10 Wetponds - Basic and Large

Purpose and Definition

A wetpond is a constructed stormwater pond that retains a permanent pool of water ("wetpool") at least during the wet season. The volume of the wetpool is related to the effectiveness of the pond in settling particulate pollutants. As an option, a shallow marsh area can be created within the permanent pool volume to provide additional treatment for nutrient removal. Peak flow control can be provided in the "live storage" area above the permanent pool. See Snohomish County EDDS Standard Drawings 5-240A and 5-240B for design information.

The following design, construction, and operation and maintenance criteria cover two wetpond applications - the basic wetpond and the large wetpond. Large wetponds are designed for higher levels of pollutant removal.

Applications and Limitations

A wetpond requires a larger area than a biofiltration swale or a sand filter, but it can be integrated to the contours of a site fairly easily. In till soils, the wetpond may hold a permanent pool of water. In more porous soils, wetponds may still be used, but water seepage from unlined cells could result in a dry pond, particularly in the summer months. Lining the first cell with a low permeability liner is one way to deal with this situation. As long as the first cell retains a permanent pool of water, this situation will not reduce the pond's effectiveness.

Wetponds work best when the water already in the pond is moved out en masse by incoming flows, a phenomenon called "plug flow." Because treatment works on this displacement principle, the wetpool storage of wetponds may be provided below the groundwater level without interfering unduly with treatment effectiveness. However, if combined with a detention function, the live storage must be above the seasonal high groundwater level.

Wetponds may be single-purpose facilities, providing only runoff treatment, or they may be combined with a detention pond to also provide flow control. If combined, the wetpond can often be stacked under the detention pond with little further loss of development area. See BMP T10.40 for a description of combined detention and wetpool facilities.

Design Criteria

Engineering standards and specifications set forth in Snohomish County EDDS Chapter 5-10 shall apply to Wetponds.

The primary design factor that determines a wetpond's treatment efficiency is the volume of the wetpool. The larger the wetpool volume, the greater the potential for pollutant removal. For a basic wetpond, the wetpool volume provided shall be equal to or greater than the total volume of runoff from the water quality design storm - the 6-month, 24-hour storm event. Alternatively, the 91st percentile, 24-hour runoff volume indicated by an approved continuous runoff modelwater quality design volume.

A large wetpond requires a wetpool volume at least 1.5 times larger than the total volume of runoff from the 6month, 24-hour storm eventwater quality design volume. Also important are the avoidance of short-circuiting and the promotion of plug flow. *Plug flow* describes the hypothetical condition of stormwater moving through the pond as a unit, displacing the "old" water in the pond with incoming flows. To prevent short-circuiting, water is forced to flow, to the extent practical, to all potentially available flow routes, avoiding "dead zones" and maximizing the time water stays in the pond during the active part of a storm.

Design features that encourage plug flow and avoid dead zones are:

- Dissipating energy at the inlet.
- Providing a large length-to-width ratio.
- Providing a broad surface for water exchange using a berm designed as a broad-crested weir to divide the wetpond into two cells rather than a constricted area such as a pipe.
- Maximizing the flowpath between inlet and outlet, including the vertical path, also enhances treatment by increasing residence time.

Sizing Procedure

Procedures for determining a wetpond's dimensions and volume are outlined below.

Step 1: Identify required wetpool volume using the SCS (now known as NRCS) curve number equations presented in Volume III, Chapter 2. A basic wetpond requires a volume equal to or greater than the total volume of runoff from the 6 month, 24 hour storm event. Alternatively, use the 91st percentile, 24 hour runoff volume indicated by an approved continuous runoff modelwater quality design volume. A large wetpond requires a volume at least 1.5 times the total volume of runoff from the 6 month, 24 hour storm event, or 1.5 times the 91st percentile, 24 hour runoff volume indicated by an approved continuous runoff modelwater quality design volume.

Step 2: Determine wetpool dimensions. Determine the wetpool dimensions satisfying the design criteria outlined below and set forth in Snohomish County EDDS Standard Drawings 5-240A and 5-240B. A simple way to check the volume of each wetpool cell is to use the following equation:

$$V = \frac{h(A_1 + A_2)}{2}$$

where V

V = wetpool volume (cf)

h = wetpool average depth (ft)

 A_1 = water quality design surface area of wetpool (sf)

 A_2 = bottom area of wetpool (sf)

Step 3: Design pond outlet pipe and determine primary overflow water surface. The pond outlet pipe shall be placed on a reverse grade from the pond's wetpool to the outlet structure. Use the following procedure to design the pond outlet pipe and determine the primary overflow water surface elevation:

- 1. Use the nomographs in Figures 5.32 -and 5.33 -to select a trial size for the pond outlet pipe sufficient to pass the on-line WQ design flow, $-Q_{wq}$ indicated by WWHM or otheran approved continuous runoff hydrologic model.
- 2. Use Figure 5.34 to determine the critical depth d_c at the outflow end of the pipe for Q_{wq} .
- 3. Use Figure 5.35 to determine the flow area A_c at critical depth.
- 4. Calculate the flow velocity at critical depth using continuity equation $(V_c = Q_{wq}/A_c)$.
- 5. Calculate the velocity head V_H -($V_H = V_c^2/2g$, where g is the gravitational constant, 32.2 feet per second).
- 6. Determine the primary overflow water surface elevation by adding the velocity head and critical depth to the invert elevation at the outflow end of the pond outlet pipe (i.e., overflow water surface elevation = outflow invert + d_c + V_H).
- 7. Adjust outlet pipe diameter as needed and repeat Steps (a) through (e).

Step 4: Determine wetpond dimensions. See Snohomish County EDDS Standard Drawings 5-240A and 5-240B.

Wetpool Geometry

• The wetpool shall be divided into two cells separated by a baffle or berm. The first cell shall contain between 25 to 35 percent of the total wetpool volume. The baffle or berm volume shall not count as part of the total wetpool volume. The term baffle means a vertical divider placed across the entire width of the pond, stopping short of the bottom. A berm is a vertical divider typically built up from the bottom, or if in a vault, connects all the way to the bottom.

<u>Intent:</u> The full-length berm or baffle promotes plug flow and enhances quiescence and laminar flow through as much of the entire water volume as possible. Alternative methods to the full-length berm or baffle that provide equivalent flow characteristics may be approved on a case-by-case basis by the Snohomish County.

- Sediment storage shall be provided in the first cell. The sediment storage shall have a minimum depth of 1 foot. A fixed sediment depth monitor should be installed in the first cell to gauge sediment accumulation unless an alternative gauging method is proposed.
- The minimum depth of the first cell shall be 4 feet, exclusive of sediment storage requirements. The depth of the first cell may be greater than the depth of the second cell.
- The maximum depth of each cell shall not exceed 8 feet (exclusive of sediment storage in the first cell). Pool depths of 3 feet or shallower (second cell) shall be planted with emergent wetland vegetation (see Vegetation).
- Inlets and outlets shall be placed to maximize the flowpath through the facility. The ratio of flowpath length to width from the inlet to the outlet shall be at least 3:1. _-The *flowpath* length is defined as the distance from the inlet to the outlet, as measured at mid-depth. The width at mid-depth can be found as follows: width = (average top width + average bottom width)/2.
- Wetponds with wetpool volumes less than or equal to 4,000 cubic feet may be single celled (i.e., no baffle or berm is required). However, it is especially important in this case that the flow path length be maximized. The ratio of flow path length to width shall be at least 4:1 in single celled wetponds, but should preferably be 5:1.
- All inlets shall enter the first cell. If there are multiple inlets, the length-to-width ratio shall be based on the average flowpath length for all inlets.
- The first cell may be lined in accordance with the liner requirements contained in Chapter 4.4 of this volume and Snohomish County EDDS Chapter 5-10.

Berms, Baffles, and Slopes

Berms, baffles, and slopes shall conform to standards and specifications set forth in Snohomish County EDDS Chapter 5-10.

- A berm or baffle shall extend across the full width of the wetpool, and tie into the wetpond side slopes. The geotechnical analysis, if required, shall address situations in which one of the two cells is empty while the other remains full of water.
- The top of the berm may extend to the WQ design water surface or be 1-foot below the WQ design water surface.

The interior berm or baffle may be a retaining wall provided that the design is prepared and stamped by a licensed civil engineer. If a baffle or retaining wall is used, it should be submerged one foot below the design water surface to discourage access by pedestrians.

Inlet and Outlet

Inlet and outlet structures shall conform to standards and specifications set forth in Snohomish County EDDS Chapter 5-10.

See Snohomish County EDDS Standard Drawings 5-240A and 5-240B.

The inlet to the wetpond shall be submerged with the inlet pipe invert a minimum of two feet from the pond bottom (not including sediment storage). The top of the inlet pipe should be submerged at least 1-foot, if possible.

- A sump is not required in the outlet structure for a wetpond that does not provide detention storage.
- The pond outlet pipe (as opposed to the manhole or type 2 catch basin outlet pipe) shall be back-sloped or have a turn-down elbow, and extend 1 foot below the WQ design water surface.
- The pond outlet pipe shall be sized, at a minimum, to pass the on-line WQ design flow.
- The overflow criteria for wetponds designed to provide only treatment are as follows:
 - 1. The requirement for primary overflow is satisfied by either the grated inlet to the outlet structure or by a birdcage above the pond outlet structure.
 - 2. The bottom of the grate opening in the outlet structure shall be set at or above the height needed to pass the WQ design flow through the pond outlet pipe. *Note: The grate invert elevation sets the overflow water surface elevation.*
 - 3. The grated opening should be sized to pass the 100-year design flow. The capacity of the outlet system should be sized to pass the peak flow for the conveyance requirements.

Access

 Access shall be provided in accordance with Chapter 30.63A SCC and Snohomish County EDDS Chapter 5-10.

Vegetation

Vegetation requirements set forth in Snohomish County EDDS Chapter 5-10 shall apply to wetponds, unless in conflict with the following requirements, in which case the following requirements will take precedence.

- Large wetponds intended for phosphorus control should not be planted within the cells, as the plants will release phosphorus in the winter when they die off.
- If the second cell of a basic wetpond is 3 feet or shallower, the bottom area shall be planted with emergent wetland vegetation. See Table 5.12 for recommended emergent wetland plant species for wetponds. Intent: Planting of shallow pond areas helps to stabilize settled sediment and prevent resuspension.
- Cattails (Typha latifolia) are not recommended because they tend to crowd out other species and will typically establish themselves anyway.

- If the wetpond discharges to a phosphorus-sensitive lake or wetland, shrubs that form a dense cover should be planted on slopes above the WQ design water surface on at least three sides. For banks that are berms, no planting is allowed if the berm is regulated by dam safety requirements. The purpose of planting is to discourage waterfowl use of the pond and to provide shading. Some suitable trees and shrubs include vine maple (Acer circinatum), wild cherry (Prunus emarginata), red osier dogwood (Cornus stolonifera), California myrtle (Myrica californica), Indian plum (Oemleria cerasiformis), and Pacific yew (Taxus brevifolia) as well as numerous ornamental species.
- Evergreen or columnar deciduous trees along the west and south sides of ponds are recommended to reduce thermal heating, except that no trees or shrubs may be planted on berms meeting the criteria of dams regulated for safety. In addition to shade, trees and shrubs also discourage waterfowl use and the attendant phosphorus enrichment problems they cause. Trees should be set back so that the branches will not extend over the pond.

Setbacks and separations

Setback and separation distances shall be in accordance with SCC 30.63A.710 and Snohomish County EDDS Chapter 5-10.

Maintenance

<u>See the Maintenance</u> requirements <u>and standards for drainage facilities are</u> set forth in Chapter 4.6 of this volume, and <u>in-Volume VI Stormwater Facility Maintenance</u>.

Species	Common Name	Notes	Maximum Depth
	INUND	ATION TO 1-FOOT	
Agrostis exarata ⁽¹⁾	Spike bent grass	Prairie to coast	to 2 feet
Carex stipata	Sawbeak sedge	Wet ground	
Eleocharis palustris	Spike rush	Margins of ponds, wet meadows	to 2 feet
Glyceria occidentalis	Western mannagrass	Marshes, pond margins	to 2 feet
Juncus tenuis	Slender rush	Wet soils, wetland margins	·
Oenanthe sarmentosa	Water parsley	Shallow water along stream and pond margins; needs saturated soils all summer	
Scirpus atrocinctus (formerly S. cyperinus)	Woolgrass	Tolerates shallow water; tall clumps	
Scirpus microcarpus	Small-fruited bulrush	Wet ground to 18 inches depth	18 inches
Sagittaria latifolia	Arrowhead		
	INUND	ATION 1 TO 2 FEET	
Agrostis exarata ⁽¹⁾	Spike bent grass	Prairie to coast	
Alisma plantago-aquatica	Water plantain		
Eleocharis palustris	Spike rush	Margins of ponds, wet meadows	
Glyceria occidentalis	Western mannagrass	Marshes, pond margins	
Juncus effusus	Soft rush	Wet meadows, pastures, wetland margins	
Scirpus microcarpus	Small-fruited bulrush	Wet ground to 18 inches depth	18 inches
Sparganium emmersum	Bur reed	Shallow standing water, saturated soils	
	INUND	ATION 1 TO 3 FEET	
Carex obnupta	Slough sedge	Wet ground or standing water	1.5 to 3 feet
Beckmania syzigachne ⁽¹⁾	Western sloughgrass	Wet prairie to pond margins	
Scirpus acutus ⁽²⁾	Hardstem bulrush	Single tall stems, not clumping	to 3 feet
Scirpus validus ⁽²⁾	Softstem bulrush		
	INUNDATION	N GREATER THAN 3 FEET	
Nuphar polysepalum	Spatterdock	Deep water	3 to 7.5 feet
Nymphaea odorata ⁽¹⁾	White waterlily	Shallow to deep ponds	to 6 feet

Notes:

Primary sources: Municipality of Metropolitan Seattle, Water Pollution Control Aspects of Aquatic Plants, 1990. Hortus Northwest, Wetland Plants for Western Oregon, Issue 2, 1991. Hitchcock and Cronquist, Flora of the Pacific Northwest, 1973.

Non-native species. Beckmania syzigachne is native to Oregon. Native species are preferred.

⁽²⁾ Scirpus tubers must be planted shallower for establishment, and protected from foraging waterfowl until established. Emerging aerial stems should project above water surface to allow oxygen transport to the roots.

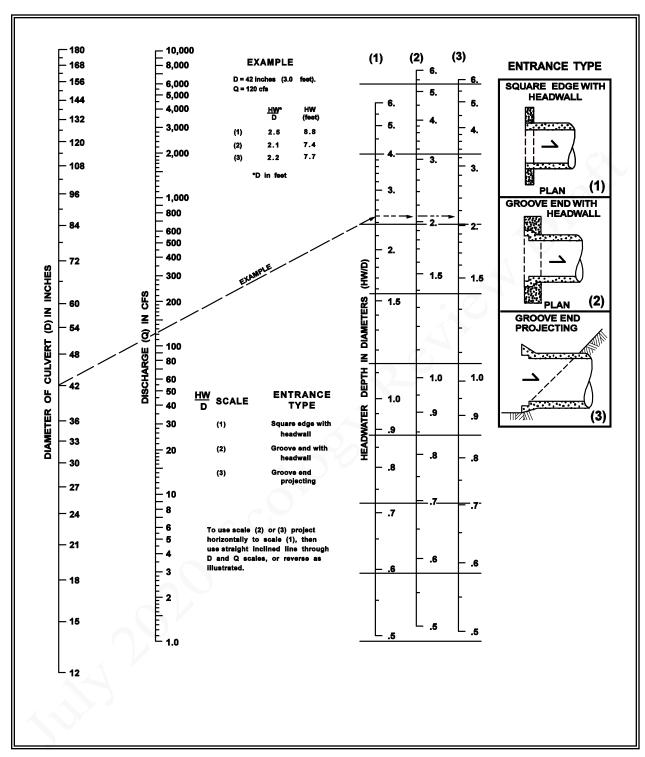


Figure 5.32 – Headwater Depth for Smooth Interior Pipe Culverts with Inlet Control

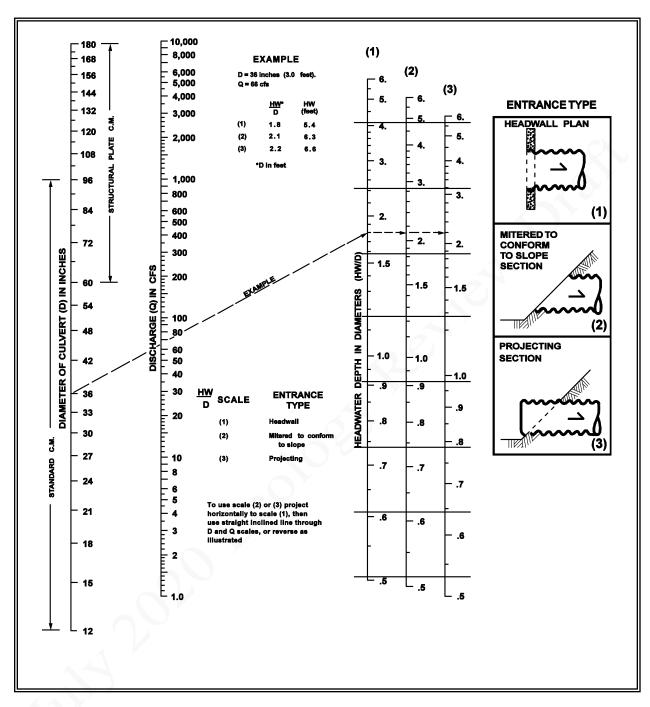


Figure 5.33 – Headwater Depth for Corrugated Pipe Culverts with Inlet Control

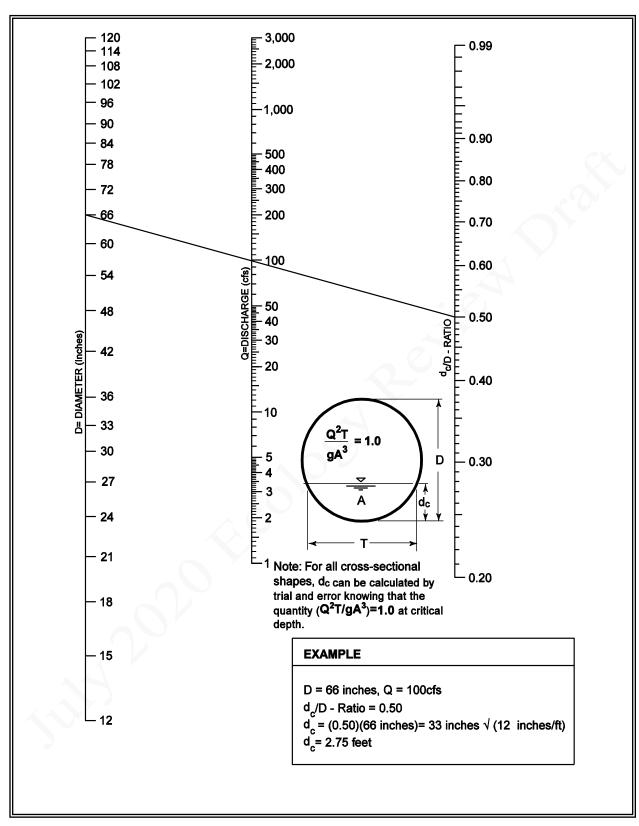


Figure 5.34 – Critical Depth of Flow for Circular Culverts

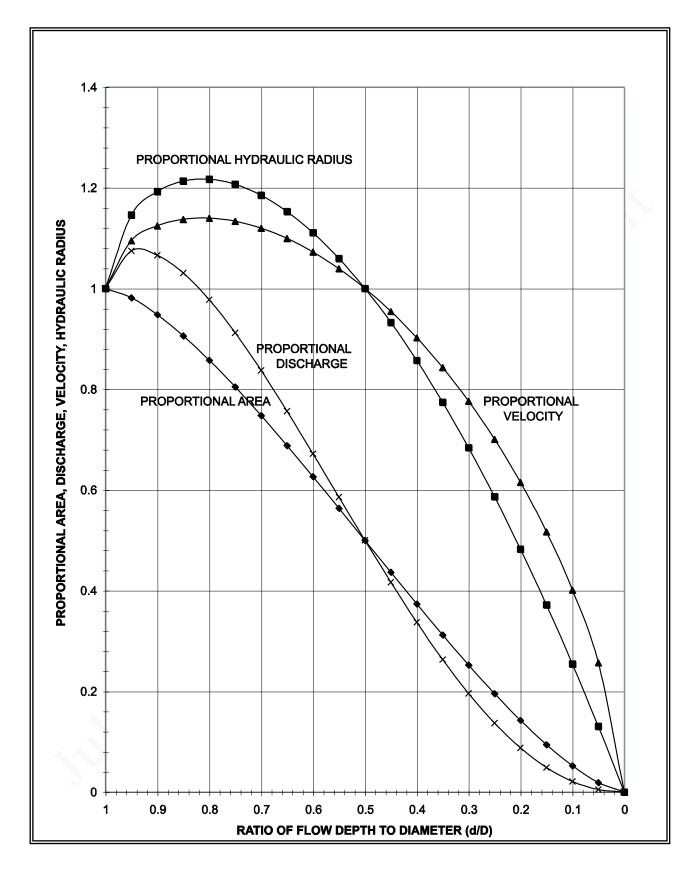


Figure 5.35 – Circular Channel Ratios

BMP T10.20 Wetvaults

Purpose and Definition

A wetvault is an underground structure similar in appearance to a detention vault, except that a wetvault has a permanent pool of water (wetpool) which dissipates energy and improves the settling of particulate pollutants. See Snohomish County EDDS Standard Drawing 5-280. Being underground, the wetvault lacks the biological pollutant removal mechanisms, such as algae uptake, present in surface wetponds.

Applications and Limitations

A wetvault can be used to provide basic treatment in certain applications or can be used as part of a treatment train. If oil control is required for a project, a wetvault may be combined with an API oil/water separator.

Design Criteria

Engineering standards and specifications set forth in Snohomish County EDDS Chapter 5-15 shall apply to vet vaults, provided that specific geometry criteria set forth below related to treatment performance shall also apply.

Sizing Procedure

The sizing procedure for a wetvault is identical to the sizing procedure for a wetpond. The wetpool volume for the wetvault shall be equal to or greater than the total volume of runoff from the 6 month, 24 hour storm event. Alternatively, the 91st percentile, 24 hour runoff volume estimated by an approved continuous runoff model may be usedwater quality design volume.

Wetpool Geometry

Same as specified for wetponds (see BMP T10.10) except for the following two modifications:

• The sediment storage in the first cell shall be an average of 1 foot. Because of the v-shaped bottom, the depth of sediment storage needed above the bottom of the side wall is roughly proportional to vault width according to the schedule below:

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ocu	ппсп	Depth

<u>Vault</u>	
Width ((from -bottom of side wall)
15'	10"
20'	9"
40'	6"
60'	4"

• The second cell shall be a minimum of 3 feet deep since planting cannot be used to prevent resuspension of sediment in shallow water as it can in open ponds.

Vault Structure

- The vault shall be separated into two cells by a wall or a removable baffle. If a wall is used, a 5-foot by 10-foot removable maintenance access must be provided for both cells. If a removable baffle is used, the following criteria apply:
 - The baffle shall extend from a minimum of 1 foot above the WQ design water surface to a minimum of 1 foot below the invert elevation of the inlet pipe.
 - The lowest point of the baffle shall be a minimum of 2 feet from the bottom of the vault, and greater if feasible.
- If the vault is less than 2,000 cubic feet (inside dimensions), or if the length-to-width ratio of the vault pool is 5:1 or greater, the baffle or wall may be omitted and the vault may be one-celled.
- The two cells of a wetvault shall not be divided into additional subcells by internal walls. If internal structural support is needed, use post and pier construction be used to support the vault lid rather than walls. Any walls used within cells must be positioned so as to lengthen, rather than divide, the flowpath.
- The bottom of the first cell shall be sloped toward the access opening. Slope shall be between 0.5 percent (minimum) and 2 percent (maximum). The second cell may be level (longitudinally) sloped toward the outlet, with a high point between the first and second cells. Sloping the second cell towards the access opening for the first cell is also acceptable.
- The vault bottom shall slope laterally a minimum of 5 percent from each side towards the center, forming a broad "v" to facilitate sediment removal. Note: More than one "v" may be used to minimize vault depth.
- Exception: Snohomish County may allow the vault bottom to be flat if removable panels are provided over the entire vault. Removable panels should be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.
- The highest point of a vault bottom must be at least 6 inches below the outlet pipe invert elevation to provide for sediment storage over the entire bottom.
- Wetvaults may be constructed using arch culvert sections provided the top area at the WQ design water surface is, at a minimum, equal to that of a vault with vertical walls designed with an average depth of 6 feet.

Inlet and Outlet

- The inlet pipe to the wetvault shall be submerged with the inlet pipe invert a minimum of 3 feet from the vault bottom. The top of the inlet pipe shall be submerged at least 1-foot.
- Unless designed as an off-line facility, the capacity of the outlet pipe and available head above the outlet pipe shall be designed to convey the 100-year design flow for developed site conditions without overtopping the vault. The available head above the outlet pipe must be a minimum of 6 inches.

- The outlet pipe shall be back-sloped or have tee section, the lower arm of which should extend 1 foot below the WQ design water surface to provide for trapping of oils and floatables in the vault.
- Snohomish County may require a bypass/shutoff valve to enable the vault to be taken offline for maintenance.

Access Requirements

The requirements set forth in Snohomish County EDDS Chapter 5-15 shall apply to wetvaults, with the following additional requirement:

• A minimum of 50 square feet of grate shall be provided over the second cell. For vaults in which the surface area of the second cell is greater than 1,250 square feet, 4 percent of the top shall be grated. This requirement may be met by one grate or by many smaller grates distributed over the second cell area. Note: a grated access door can be used to meet this requirement.

Access Roads

The requirements set forth in Snohomish County EDDS Chapter 5-15 shall apply to wetvaults.

Setbacks and separations

Setback and separation distances shall be in accordance with SCC 30.63A.710 and Snohomish County EDDS Chapter 5-15.

Maintenance

<u>See Maintenance</u> requirements <u>and standards for drainage facilities are</u> set forth in <u>Chapter 7.53.140 SCC</u>, <u>and Volume V</u>, Chapter 4.6 of this <u>manual volume</u>, and <u>Volume VI Stormwater Facility Maintenance</u>.

BMP T10.30 Stormwater Treatment Wetlands

Purpose and Definition

In land development situations, wetlands are usually constructed for two main reasons: to replace or mitigate impacts when natural wetlands are filled or impacted by development (mitigation wetlands), and to treat stormwater runoff (stormwater treatment wetlands). Stormwater treatment wetlands are shallow man-made ponds that are designed to treat stormwater through the biological processes associated with emergent aquatic plants (see the stormwater wetland details in Figure 5.34 and Figure 5.35.

Wetlands created to mitigate disturbance impacts, such as filling, may not also be used as stormwater treatment facilities. This is because of the different, incompatible functions of the two kinds of wetlands. Mitigation wetlands are intended to function as full replacement habitat for fish and wildlife, providing the same functions and harboring the same species diversity and biotic richness as the wetlands they replace. Stormwater treatment wetlands are used to capture and transform pollutants, just as wetponds are, and over time pollutants will concentrate in the sediment. This is not a healthy environment for aquatic life. Stormwater treatment wetlands are used to capture pollutants in a managed environment so that they will not reach natural wetlands and other ecologically important habitats. In addition, vegetation must occasionally be harvested and sediment dredged in stormwater treatment wetlands, further interfering with use for wildlife habitat.

In general, stormwater wetlands perform well to remove sediment, metals, and pollutants that bind to humic or organic acids. Phosphorus removal in stormwater wetlands is highly variable.

Applications and Limitations

This stormwater wetland design occupies about the same surface area as wetponds, but has the potential to be better integrated aesthetically into a site because of the abundance of emergent aquatic vegetation. The most critical factor for a successful design is the provision of an adequate supply of water for most of the year. Careful planning is needed to be sure sufficient water will be retained to sustain good wetland plant growth. Since water depths are shallower than in wetponds, water loss by evaporation is an important concern. Stormwater wetlands are a good WQ facility choice in areas with high winter groundwater levels.

Design Criteria

When used for stormwater treatment, stormwater wetlands employ some of the same design features as wetponds. However, instead of gravity settling being the dominant treatment process, pollutant removal mediated by aquatic vegetation and the microbiological community associated with that vegetation becomes the dominant treatment process. Thus when designing wetlands, water volume is not the dominant design criteria. Rather, factors which affect plant vigor and biomass are the primary concerns.

Sizing Procedure

Step 1: The volume of a basic wetpond is used as a template for sizing the stormwater wetland. The design volume is the total volume of runoff from the 6-month, 24-hour storm event.

Alternatively, the 91st percentile, 24-hour runoff volume estimated by an approved continuous runoff model may be usedwater quality design volume.

- Step 2: Calculate the surface area of the stormwater wetland. The surface area of the wetland shall be the same as the top area of a wetpond sized for the same site conditions. Calculate the surface area of the stormwater wetland by using the volume from Step 1 and dividing by the average water depth (use 3 feet).
- Step 3: Determine the surface area of the first cell of the stormwater wetland. Use the volume determined from Criterion 2 under "Wetland Geometry", and the actual depth of the first cell.
- Step 4: Determine the surface area of the wetland cell. Subtract the surface area of the first cell (Step 3) from the total surface area (Step 2).
- Step 5: Determine water depth distribution in the second cell. Decide if the top of the dividing berm will be at the surface or submerged (designer's choice). Adjust the distribution of water depths in the second cell according to Criterion 8 under "Wetland Geometry" below. Note: This will result in a facility that holds less volume than that determined in Step 1 above. This is acceptable.
- Step 6: Choose plants. See Table 5.13 for a list of plants recommended for wetpond water depth zones, or consult a wetland scientist.

Wetland Geometry

- 1. Stormwater wetlands shall consist of two cells, a presettling cell and a wetland cell.
- 2. The presettling cell shall contain approximately 33 percent of the wetpool volume calculated in Step 1 above.
- 3. The depth of the presettling cell shall be between 4 feet (minimum) and 8 feet (maximum), excluding sediment storage.
- 4. One-foot of sediment storage shall be provided in the presettling cell.
- 5. The wetland cell shall have an average water depth of about 1.5 feet (plus or minus 3 inches).
- 6. The "berm" separating the two cells shall be shaped such that its downstream side gradually slopes to form the second shallow wetland cell (see the section view in Figure 5.34). Alternatively, the second cell may be graded naturalistically from the top of the dividing berm (see Criterion 8 below).
- 7. The top of berm shall be either at the WQ design water surface or submerged 1-foot below the WQ design water surface, as with wetponds. Berm standards and specifications set forth in Snohomish County EDDS Chapter 5-10 apply
- 8. Two examples are provided for grading the bottom of the wetland cell. One example is a shallow, evenly graded slope from the upstream to the downstream edge of the wetland cell (see Figure 5.36). The second example is a "naturalistic" alternative, with the specified range of depths intermixed throughout the second cell (see Figure 5.37). A distribution of depths shall be provided in the wetland cell depending on whether the dividing berm is at the water surface or submerged (see Table 5.13 below). The maximum depth is 2.5 feet in either configuration. Other configurations within the wetland geometry constraints listed above may be approved by Snohomish County.

Table 5.13 – Distribution of Depths in Wetland Cell			
Dividing Berm at WQ Design Water Surface		Dividing Berm Submerged 1-Foot	
Depth Range (feet)	Percent	Depth Range (feet)	Percent
0.1 to 1	25	1 to 1.5	40
1 to 2	55	1.5 to 2	40
2 to 2.5	20	2 to 2.5	20

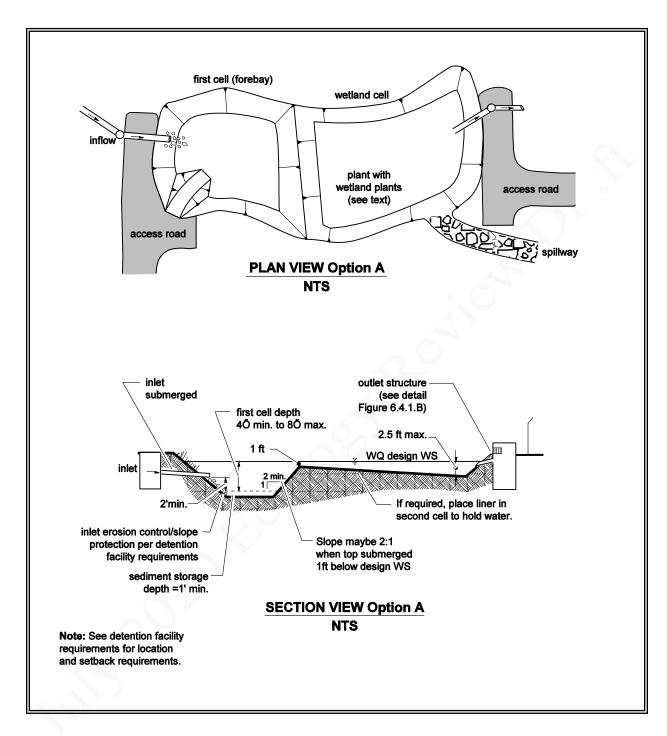


Figure 5.36 – Stormwater Wetland – Option One

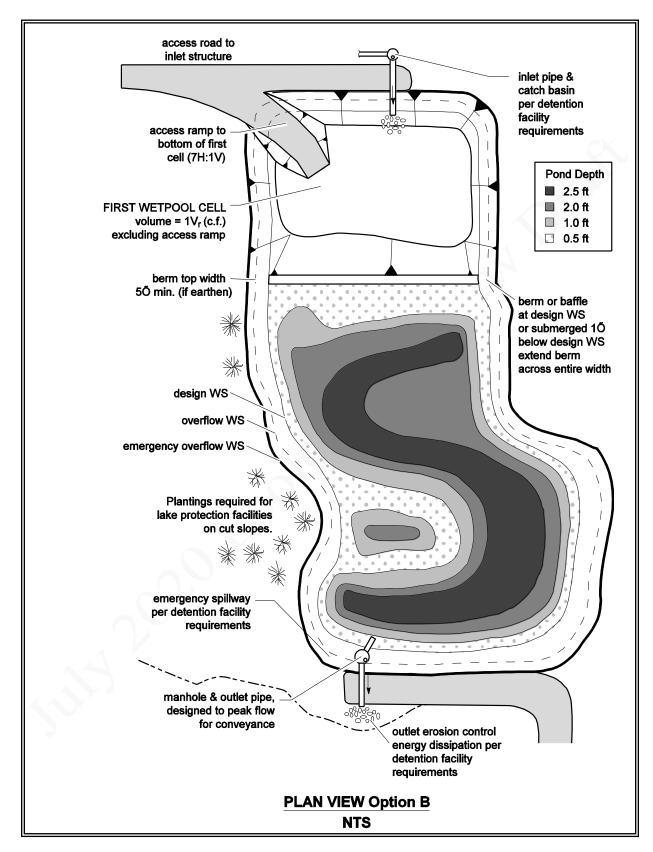


Figure 5.37 – Stormwater Wetland — Option Two

Lining Requirements

The first cell must retain at least three feet of water year-round. The second cell must retain water for at least 10 months of the year. A liner may be needed to achieve these conditions. Liners shall meet the requirements set forth in Chapter 4.4 of this volume. If a liner is needed, either a treatment liner or a low permeability liner may be used, provided the conditions are met. The need for a liner shall be determined by conducting a hydrologic analysis using a complete precipitation record and accounting for evapotranspiration losses and soil characteristics.

If a low permeability liner is used, a minimum of 18 inches of native soil amended with good topsoil or compost (one part compost mixed with 3 parts native soil) must be placed over the liner. For geomembrane liners, a soil depth of 3 feet is recommended to prevent damage to the liner during planting. Hydric soils are not required.

Inlet and Outlet

See inlet and outlet requirements for Wetponds, BMP T10.10. Materials and engineering standards and specifications set forth in Snohomish County EDDS Chapter 5-10 shall apply.

Access

Access shall be provided in accordance with Chapter 30.63A SCC and Snohomish County EDDS Chapter 5-10.

Vegetation

The wetland cell shall be planted with emergent wetland plants following the recommendations given in Table 5.16 or the recommendations of a wetland specialist. Note: Cattails (Typha latifolia) are not recommended. They tend to escape to natural wetlands and crowd out other species. In addition, the shoots die back each fall and will result in oxygen depletion in the wetpool unless they are removed.

Setbacks and separations

Setback and separation distances shall be in accordance with SCC 30.63A.710 and Snohomish County EDDS Chapter 5-10.

Construction Criteria

- Construction and maintenance considerations are the same as for wetponds.
- Construction of the naturalistic alternative (Option 2) can be easily done by first excavating the entire area to the 1.5-foot average depth. Then soil subsequently excavated to form deeper areas can be deposited to raise other areas until the distribution of depths indicated in the design is achieved.

Maintenance

Maintenance requirements for wetponds shall apply to stormwater treatment wetlands.

Maintenance See requirements and standards for drainage facilities are set forth in Chapter 4.6 of this volume and in Volume VI Stormwater Facility Maintenance.

BMP T10.40 Combined Detention and Wetpool Facilities

Purpose and Definition

Combined detention and WQ wetpool facilities have the appearance of a detention facility but contain a permanent pool of water as well. The following design procedures, requirements, and recommendations cover differences in the design of the stand-alone WQ facility when combined with detention storage. The following combined facilities are addressed:

- Detention/wetpond (basic and large)
- Detention/wetvault
- Detention/stormwater wetland.

There are two sizes of the combined wetpond, a basic and a large, but only a basic size for the combined wetvault and combined stormwater wetland. The facility sizes (basic and large) are related to the pollutant removal goals.

Applications and Limitations

Combined detention and water quality facilities are very efficient for sites that also have detention requirements. The water quality facility may often be placed beneath the detention facility without increasing the facility surface area. However, the fluctuating water surface of the live storage will create unique challenges for plant growth and for aesthetics alike.

The basis for pollutant removal in combined facilities is the same as in the stand-alone WQ facilities. However, in the combined facility, the detention function creates fluctuating water levels and added turbulence. For simplicity, the positive effect of the extra live storage volume and the negative effect of increased turbulence are assumed to balance, and are thus ignored when sizing the wetpool volume. _-For the combined detention/stormwater wetland, criteria that limit the extent of water level fluctuation are specified to better ensure survival of the wetland plants.

Unlike the wetpool volume, the live storage component of the facility should be provided above the seasonal high water table.

Design

Combined Detention and Wetpond (Basic and Large)

Typical design details and concepts for a combined detention and wetpond are shown in Figures 5.38 - 5.40. The detention portion of the facility shall meet the design criteria and sizing procedures set forth in Volume III.

Sizing Procedure

The sizing procedure for combined detention and wetponds are identical to those outlined for wetponds and for detention facilities. The wetpool volume for a combined facility shall be equal to or greater than the total volume of runoff from the 6-month, 24-hour storm event.

Alternatively, the 91st percentile, 24-hour runoff volume estimated by an approved continuous

runoff model may be used to size the wetpoolwater quality design volume. Follow the standard procedure specified in Volume III to size the detention portion of the pond.

Detention and Wetpool Geometry

- The wetpool and sediment storage volumes shall not be included in the required detention volume.
- The "Wetpool Geometry" criteria for wetponds (see BMP T10.10) shall apply with the following modifications/clarifications:

Criterion 1: The permanent pool may be made shallower to take up most of the pond bottom, or deeper and positioned to take up only a limited portion of the bottom. Note, however, that having the first wetpool cell at the inlet allows for more efficient sediment management than if the cell is moved away from the inlet. Wetpond criteria governing water depth must, however, still be met.

Criterion 2: The minimum sediment storage depth in the first cell is 1-foot. The 6 inches of sediment storage required for detention ponds does not need to be added to this, but 6 inches of sediment storage must be added to the second cell to comply with the detention sediment storage requirement.

Berms, Baffles, and Slopes

See Wetponds, BMP T10.10. Engineering standards and specifications set forth in Snohomish County EDDS Chapter 5-10 shall apply.

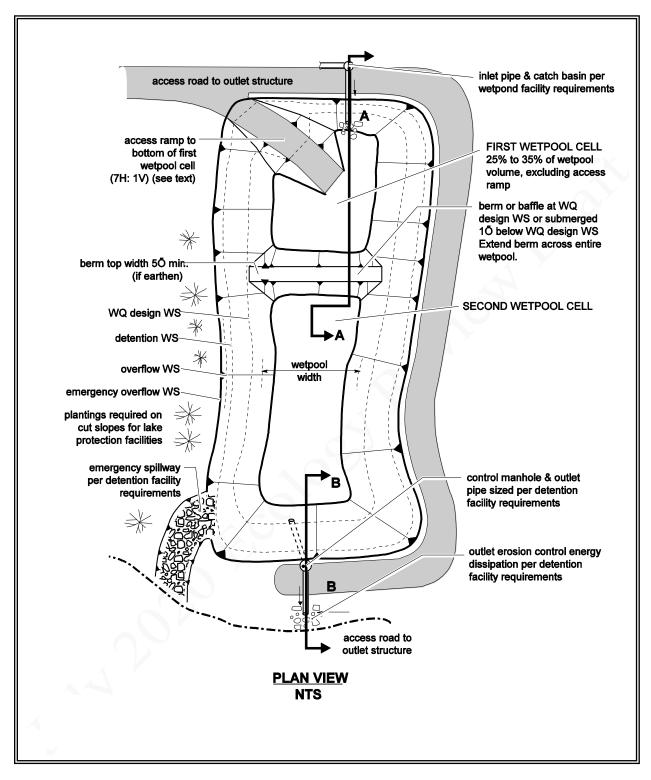


Figure 5.38 – Combined Detention and Wetpond

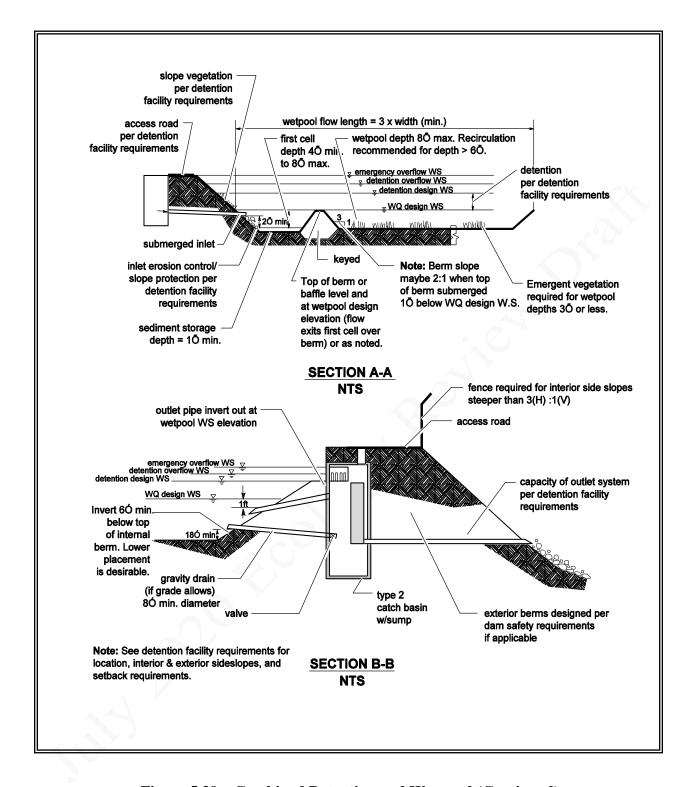


Figure 5.39 – Combined Detention and Wetpond (Continued)

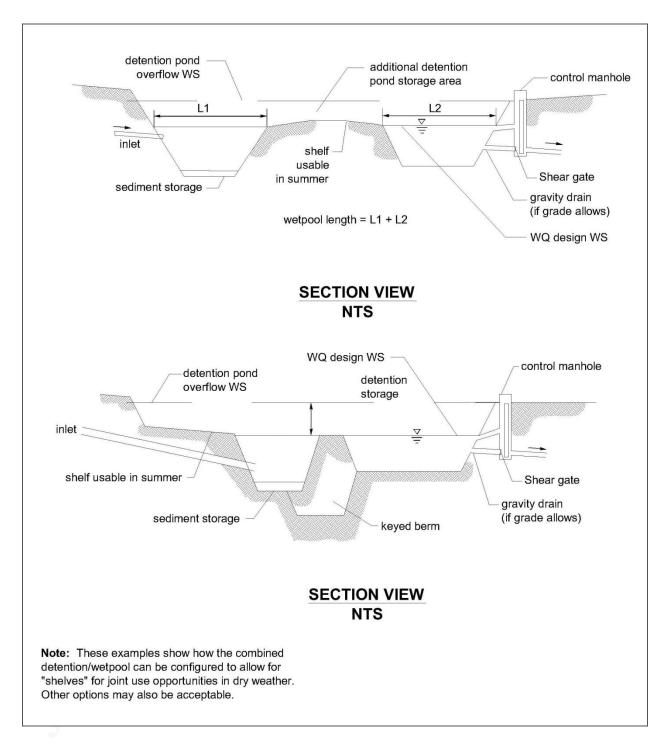


Figure 5.40 – Alternative Configurations of Detention and Wetpool Areas

Inlet and Outlet

The "Inlet and Outlet" criteria for wetponds shall apply with the following modifications:

- A sump must be provided in the outlet structure of combined ponds.
- The detention flow restrictor and its outlet pipe shall be designed according to the requirements for detention ponds (see Volume III).

Access and Setbacks

Same as for wetponds.

Planting Requirements

Same as for wetponds.

Combined Detention and Wetvault

The sizing procedure for combined detention and wetvaults is identical to those outlined for wetvaults and for detention facilities. The wetvault volume for a combined facility shall be equal to or greater than the total volume of runoff from the 6-month, 24-hour storm event.

Alternatively, the 91st percentile, 24-hour runoff volume estimated by an approved continuous runoff model may be used to size the wetpool portion of vaultwater quality design volume.

Follow the standard procedure specified in Volume III to size the detention portion of the vault.

The design criteria for detention vaults and wetvaults must both be met, except for the following modifications or clarifications:

- The minimum sediment storage depth in the first cell shall average 1-foot. The 6 inches of sediment storage required for detention vaults does not need to be added to this, but 6 inches of sediment storage must be added to the second cell to comply with detention vault sediment storage requirements.
- The oil retaining baffle shall extend a minimum of 2 feet below the WQ design water surface.

Note: If a vault is used for detention as well as water quality control, the facility may not be modified to function as a baffle oil/water separator as allowed for wetvaults in BMP T10.20. This is because the added pool fluctuation in the combined vault does not allow for the quiescent conditions needed for oil separation.

Combined Detention and Stormwater Wetland

The sizing procedure for combined detention and stormwater wetlands is identical to those outlined for stormwater wetlands and for detention facilities. Follow the procedure specified in BMP T10.30 to determine the stormwater wetland size. Follow the standard procedure specified in Volume III to size the detention portion of the wetland.

Design criteria

The design criteria for detention ponds and stormwater wetlands must both be met, except for the following modifications or clarifications:

- The "Wetland Geometry" criteria for stormwater wetlands (see BMP T10.30) are modified as follows:
- The minimum sediment storage depth in the first cell is 1-foot. The 6 inches of sediment storage required for detention ponds does not need to be added to this, nor does the 6 inches of sediment storage in the second cell of detention ponds need to be added.

Inlet and outlet

The "Inlet and Outlet" criteria for wetponds shall apply with the following modifications:

- A sump must be provided in the outlet structure of combined facilities.
- The detention flow restrictor and its outlet pipe shall be designed according to the requirements for detention ponds (see Volume III).

Planting requirements

The "Planting Requirements" for stormwater wetlands are modified to use the following plants which are better adapted to water level fluctuations:

Scirpus acutus (hardstem bulrush) ____2 - 6' depth
Scirpus microcarpus (small-fruited bulrush) 1 - 2.5' depth
Sparganium emersum (burreed) 1 - 2' depth
Sparganium eurycarpum (burreed) ____1 - 2' depth
Veronica sp. (marsh speedwell) 0 - 1' depth

In addition, the shrub Spirea douglasii (Douglas spirea) may be used in combined facilities.

Water Level Fluctuation Restrictions

The difference between the WQ design water surface and the maximum water surface associated with the 2-year runoff shall not be greater than 3 feet. If this restriction cannot be met, the size of the stormwater wetland must be increased. The additional area may be placed in the first cell, second cell, or both. If placed in the second cell, the additional area need not be planted with wetland vegetation or counted in calculating the average depth. Note: this criterion is not intended to protect native wetland plant communities and shall not be applied to natural wetlands.

Maintenance

Maintenance requirements for wetponds and detention ponds shall apply to combined detention and wetpool facilities. See requirements and standards set forth in Chapter 4.6 of this volume and in Volume VI Stormwater Facility Maintenance

Chapter 11 Oil and Water Separators

This chapter provides a discussion of oil and water separators, including their application and design criteria. BMPs are described for baffle type and coalescing plate separators.

11.1 Purpose of Oil and Water Separators

To remove oil and other water-insoluble hydrocarbons, and settleable solids from stormwater runoff.

11.2 Description

Oil and water separators are typically the American Petroleum Institute (API) (also called baffle type) (American Petroleum Institute, 1990) or the coalescing plate (CP) type using a gravity mechanism for separation. See Snohomish County EDDS Standard Drawings 5-310 and 5-315. Oil removal separators typically consist of three bays; forebay, separator section, and the afterbay. The CP separators need considerably less space for separation of the floating oil due to the shorter travel distances between parallel plates. A spill control (SC) separator (Figure 5.41) is a simple catchbasin with a T-inlet for temporarily trapping small volumes of oil. The spill control separator is included here for comparison only and is not designed for, or to be used for treatment purposes.

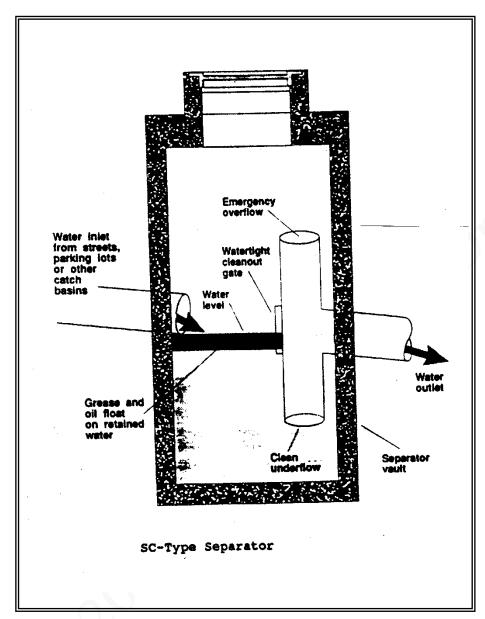


Figure 5.41 – Spill Control Separator (not for oil treatment)

11.3 Performance Objectives

Oil and water separators should be designed to remove oil and TPH down to 15 mg/L at any time and 10 mg/L on a 24-hr average, and produce a discharge that does not cause an ongoing or recurring visible sheen in the stormwater discharge, or in the receiving water. (See also Chapter 3 of this volume).

11.4 Applications/Limitations

The following are potential applications of oil and water separators where free oil is expected to be present at treatable high concentrations and sediment will not overwhelm the separator. For low concentrations of oil, other treatments may be more applicable. These include sand filters and emerging technologies.

- Commercial and industrial areas including petroleum storage yards, vehicle maintenance facilities, manufacturing areas, airports, utility areas (water, electric, gas), and fueling stations.
- Facilities that would require oil control BMPs under the high-use site threshold described in Chapter 2 including parking lots at convenience stores, fast food restaurants, grocery stores, shopping malls, discount warehouse stores, banks, truck fleets, auto and truck dealerships, and delivery services.
- Without intense maintenance oil/water separators may not be sufficiently effective in achieving oil and TPH removal down to required levels.
- Pretreatment should be considered if the level of TSS in the inlet flow would cause clogging or otherwise impair the long-term efficiency of the separator.
- For inflows from small drainage areas (fueling stations, maintenance shops, etc.) a coalescing plate (CP) type separator is typically considered, due to space limitations. However, if plugging of the plates is likely, then a new design basis for the baffle type API separator may be considered on an experimental basis.

11.5 Site Suitability

Consider the following site characteristics:

- Sufficient land area
- Adequate TSS control or pretreatment capability
- Compliance with environmental objectives
- Adequate influent flow attenuation and/or bypass capability
- Sufficient access for operation and maintenance (O & M)

11.6 Design Criteria-General Considerations

NOTE: Engineering standards and specifications for oil / water separators are set forth in Snohomish County EDDS Chapter 5-19.

The following are design criteria applicable to API and CP oil/water separators:

- If practicable, determine oil/grease (or TPH) and TSS concentrations, lowest temperature, pH; and empirical oil rise rates in the runoff, and the viscosity, and specific gravity of the oil. Also determine whether the oil is emulsified or dissolved. Do not use oil/water separators for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols, and alcohols.
- Locate the separator off-line and bypass the incremental portion of flows that exceed the off-line -15-minute, water quality design flow rate multiplied by the ratio indicated in Figure 5.27. If it is necessary to locate the separator on-line, try to minimize the size of the area needing oil control, and use the on-line water quality design flow rate multiplied by the ratio indicated in Figure 5.26.
- Use only impervious conveyances for oil contaminated stormwater.
- Specify appropriate performance tests after installation and shakedown, and/or certification by a professional engineer that the separator is functioning in accordance with design objectives. Expeditious corrective actions must be taken if it is determined the separator is not achieving acceptable performance levels.
- Add pretreatment for TSS that could cause clogging of the CP separator, or otherwise impair the long-term effectiveness of the separator.

Criteria for Separator Bays

- Multiply the size of the separator bay determined for the water quality design flow rate by the correction factor ratio indicated in Figure 5.18 of this volume (assuming an off-line facility.
- To collect floatables and settleable solids, design the surface area of the forebay at ≥ 20 ft² per 10,000 ft² of area draining to the separator. The length of the forebay should be 1/3-1/2 of the length of the entire separator. Include roughing screens for the forebay or upstream of the separator to remove debris, if needed. Screen openings should be about 3/4 inch.
- Include a submerged inlet pipe with a turn-down elbow in the first bay at least two feet from the bottom. The outlet pipe should be a Tee, sized to pass the design peak flow and placed at least 12 inches below the water surface.
- Include a shutoff mechanism at the separator outlet pipe.
- Use absorbents and/or skimmers in the afterbay as needed.

Criteria for Baffles

- Oil retaining baffles (top baffles) should be located at least at 1/4 of the total separator length from the outlet and should extend down at least 50% of the water depth and at least 1 ft. from the separator bottom.
- Baffle height to water depth ratios should be 0.85 for top baffles and 0.15 for bottom baffles.

11.7 Oil and Water Separator BMPs

Two BMPs are described in this section. BMP T11.10 for baffle type separators, and BMP T11.11 for coalescing plate separators.

BMP T11.10 API (Baffle type) Separator Bay

Design Criteria

The criteria for small drainages is based on V_h, V_t, residence time, width, depth, and length considerations. As a correction factor API's turbulence criteria is applied to increase the length.

For drainage areas less than two acres, use the design hydraulic horizontal velocity, V_h , for the design V_h/V_t ratio rather than the API minimum of V_h/V_t = 15.

The following is the sizing procedure using modified API criteria:

- Determine the oil rise rate, Vt, in cm/sec, using Stokes Law, or empirical determination, or 0.033 ft./min for 60μ oil. The application of Stokes' Law to site-based oil droplet sizes and densities, or empirical rise rate determinations recognizes the need to consider actual site conditions. In those cases the design basis would not be the 60 micron droplet size and the 0.033 ft/min, rise rate.
- Stokes Law equation for rise rate, Vt (cm/sec):

$$Vt = [(g)(\rho w - \rho o)(d^2)] / [(18*\mu w)]$$

w₩here:

Vt = the rise rate of the oil droplet (cm/s or ft/sec)

g = acceleration due to gravity (cm/s² or ft/s²)

 $\rho w = \text{density of water at the design temperature } (g/cm^3 \text{ or } lbm/ft^3)$

 $\rho o = \text{density of oil at the design temperature } (g/cm^3 \text{ or } lbm/ft^3)$

d = oil droplet diameter (cm or ft)

 $\mu w = absolute viscosity of the water (g/cm-s or lbm/ft-s)$

use:

- o oil particle size diameter, D=60 microns (0.006 cm)
- o $\rho w = 0.999 \text{ gm/cc. at } 32^{\circ} \text{ F}$
- o po: Select conservatively high oil density. For example, if diesel oil @ $\rho o = 0.85$ gm/cc and motor oil @ $\rho o = 0.90$ can be present then use $\rho o = 0.90$ gm/cc
- o $\mu w = 0.017921$ poise, gm/cm-sec. at $T_w=32$ °F
- Separator water depth, $d \ge 3 \le 8$ feet (to minimize turbulence)
- o Separator width, 6-20 feet
- \circ Depth/width (d/w) of 0.3-0.5

For Stormwater Inflow from Drainages under 2 Acres:

- 1. Determine V_t and select depth and width of the separator section based on above criteria.
- 2. Calculate the minimum residence time (t_m) of the separator at depth d:

$$t_m = d/V_t$$

3. Calculate the horizontal velocity of the bulk fluid, V_h , vertical cross-sectional area, A_v , and actual design V_h/V_t

$$V_h = Q/dw = Q/A_v (V_h \text{ maximum at } < 2.0 \text{ ft/min.})$$

Q = (k) the ratio indicated in Figure 5.28 (on-line) or Figure 5.29 (off-line) for the site location multiplied by the 15 minute Water Quality design flow rate water quality design flow rate in ft³/min, at minimum residence time, t_m

At V_h/V_t determine F, turbulence and short-circuiting factor using Figure 5.42.

4. Calculate the minimum length of the separator section, l(s), using:

$$\begin{split} l(s) &= FQt_m/wd = F(V_h/V_t)d \\ l(t) &= l(f) + l(s) + l(a) \\ l(t) &= l(t)/3 + l(s) + l(t)/4 \end{split}$$

l(t) = total length of 3 bays = "L" in Snohomish County EDDS Standard Drawing 5-310

l(f) = length of forebay

l(a) = length of afterbay

5. Calculate $V = l(s)wd = FQt_m$, and $A_h = wl(s)$

V = minimum hydraulic design volume

 A_h = minimum horizontal area of the separator

For Stormwater Inflow from Drainages > 2 Acres:

Use $V_h = 15 V_t$ and $d = (Q/2V_h)^{1/2}$ (with d/w = 0.5) and repeat above calculations 3-5.

Setbacks and separations

Setback and separation distances shall be in accordance with SCC 30.63A.710 and Snohomish County EDDS Chapter 5-15.

Maintenance

<u>See Maintenance</u> requirements <u>and standards</u> for drainage facilities are set forth in Chapter 4.6 of this volume, and in Volume VI Stormwater Facility Maintenance.

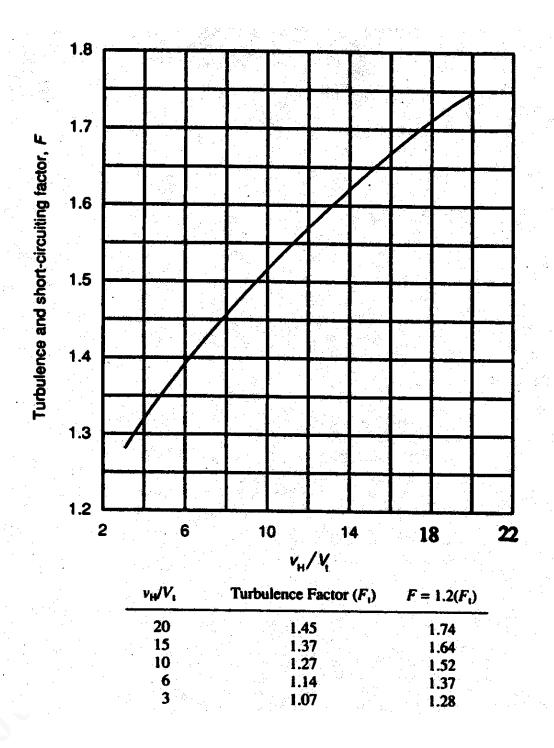


Figure 5.42 – Recommended Values of F for Various Values of v_H/Vt

BMP T11.11 Coalescing Plate (CP) Separator Bay

Design Criteria

Calculate the projected (horizontal) surface area of plates needed using the following equation:

$$Ah = Q/Vt = [Q] / [(.00386) * ((Sw - So)/(\mu w))]$$

Ah = horizontal surface area of the plates (ft²)

Vt = rise rate of the oil droplet (ft/min)

Q = (k) the ratio indicated in Figure 5.26 (on-line) or Figure 5.27 (off-line) for the site location multiplied by the 15 minute Water Quality design flow rate water quality design flow rate in ft³/min, at minimum residence time, t_m

 S_w = specific gravity of water at the design temperature

 S_0 = specific gravity of oil at the design temperature

 μ w = absolute viscosity of the water (poise)

The above equation is based on an oil droplet diameter of 60 microns

- Plate spacing should be a minimum of 3/4 in (perpendicular distance between plates).
- Select a plate angle between 45° to 60° from the horizontal.
- Locate plate pack at least 6 inches from the bottom of the separator for sediment storage
- Add 12 inches minimum head space from the top of the plate pack and the bottom of the vault cover.
- Design inlet flow distribution and baffles in the separator bay to minimize turbulence, short-circuiting, and channeling of the inflow especially through and around the plate packs of the CP separator. The Reynolds Number through the separator bay should be <500 (laminar flow).
- Include forebay for floatables and afterbay for collection of effluent
- The sediment-retaining baffle must be upstream of the plate pack at a minimum height of 18 in.
- Design plates for ease of removal, and cleaning with high-pressure rinse or equivalent.

Setbacks and separations

Setback and separation distances shall be in accordance with SCC 30.63A.710 and Snohomish County EDDS Chapter 5-15.

Maintenance

<u>See Maintenance</u> requirements <u>and standards</u> for drainage facilities are set forth in Chapter 4.6 of this volume, and in Volume VI Stormwater Facility Maintenance.

Chapter 12 Other BMPs and Technologies Approved by the Washington State Department of Ecology

Ecology has assigned Use Level Designations (ULDs) to systems and technologies evaluated according to the Technical Assessment Protocol - Ecology (TAPE) and the Chemical Technical Assessment Protocol (CTAPE). These protocols were developed to allow Ecology to determine whether a system or technology meets the performance criteria for BMPs in the 2014 Ecology Stormwater Management Manual for Western Washington.

The three ULDs used by Ecology are General Statewide Use Level Designation (GULD), Conditional Use Level Designation (CULD), and Pilot Use Level Designation (PULD). Snohomish County will allow use of systems and technologies with a GULD without a code modification, provided that they are designed and constructed in accordance with the information presented on Ecology's website. Systems and technologies with CULDs or PULDs may only be used in Snohomish County with approval through the code modification process.

Information about Ecology's TAPE process is available at http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html

Appendix V-A Basic Treatment Receiving Waters

1. All salt waterbodies

2. <u>Rivers</u> <u>Upstream Point for Exemption</u>

Skykomish Beckler River

Snohomish Snoqualmie River

Snoqualmie Middle and North Fork Confluence

Stillaguamish North and South Fork Confluence

North Fork Stillaguamish Boulder River

South Fork Stillaguamish Canyon Creek

Suiattle Darrington

3. <u>Lakes</u> No lakes in Snohomish County are Basic Treatment

Receiving Waters

Appendix V-B Recommended Modifications to ASTM D 2434 When Measuring Hydraulic Conductivity for Bioretention Soil Mixes (per Ecology 2014 Stormwater Management Manual for Western Washington)

Proctor method ASTM D1557 Method C (6-inch mold) shall be used to determine maximum dry density values for compaction of bioretention soil sample. Sample preparation for the Proctor test shall be amended in the following ways:

- 1. Maximum grain size within the sample shall be no more than ½ inches in size.
- 2. Snip larger organic particles (if present) into ½ inch long pieces.
- 3. When adding water to the sample during the Proctor test, allow the sample to pre-soak for at least 48 hours to allow the organics to fully saturate before compacting the sample. This pre-soak ensures the organics have been fully saturated at the time of the test.

ASTM D2434 shall be used and amended in the following ways:

1. Apparatus:

- a. 6-inch mold size shall be used for the test.
- b. If using porous stone disks for the testing, the permeability of the stone disk shall be measured before and after the soil tests to ensure clogging or decreased permeability has not occurred during testing.
- c. Use the confined testing method, with 5- to 10-pound force spring
- d. Use de-aired water.

2. Sample:

- a. Maximum grain size within the sample shall not be more than ½ inch in size.
- b. Snip larger organic particles (if present) into ½-inch long pieces.
- c. Pre-soak the sample for at least 48 hours prior to loading it into the mold. During the pre-soak, the moisture content shall be higher than optimum moisture but less than full saturation (i.e., there shall be no free water). This pre-soak ensures the organics have been fully saturated at the time of the test.

3. Preparation of Sample:

- a. Place soil in cylinder via a scoop.
- b. Place soil in 1-inch lifts and compact using a 2-inch-diameter round tamper. Pre-weigh how much soil is necessary to fill 1-inch lift at 85% of maximum dry density, then tamp to 1-inch thickness. Once mold is full, verify that density is at 85% of maximum dry density (+ or -0.5%). Apply vacuum (20 inches Hg) for 15 minutes before inundation.
- c. Inundate sample slowly under a vacuum of 20 inches Hg over a period of 60 to 75 minutes.

- d. Slowly remove vacuum (> 15 seconds).
- e. Sample shall be soaked in the mold for 24 to 72 hours before starting test.

4. Procedure:

- a. The permeability test shall be conducted over a range of hydraulic gradients between 0.1 and 2.
- b. Steady state flow rates shall be documented for four consecutive measurements before increasing the head.
- c. The permeability test shall be completed within one day (one-day test duration).